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(54) **SURGICAL ROBOT SYSTEM HAVING TOOL FOR MINIMALLY INVASIVE SURGERY**

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A61B 19/00 (2006.01)

A61B 17/29 (2006.01)

(52) **U.S. Cl.**

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2019/2223; **A61B 2019/2234**; **A61B 2019/2242**; **A61B 2019/2276**; **A61B 2019/5227**; **B25J 9/0018**; **B25J 9/06**

USPC 606/1, 130; 600/104
See application file for complete search history.

(56)

References Cited

U.S. PATENT DOCUMENTS

4,853,874	A	8/1989	Iwamoto et al.	
5,710,870	A *	1/1998	Ohm et al.	700/263
5,779,623	A	7/1998	Bonnell	
5,807,377	A *	9/1998	Madhani et al.	606/1
5,820,623	A *	10/1998	Ng	606/1
5,931,832	A *	8/1999	Jensen	606/1
6,102,850	A	8/2000	Wang et al.	
6,197,017	B1 *	3/2001	Brock et al.	606/1
6,331,181	B1	12/2001	Tierney et al.	
6,676,684	B1 *	1/2004	Morley et al.	606/205
6,786,896	B1	9/2004	Madhani et al.	
6,905,491	B1	6/2005	Wang et al.	
2008/0071291	A1	3/2008	Duval et al.	

* cited by examiner

FOREIGN PATENT DOCUMENTS

JP	2006061364	A	3/2006
KR	1020080027224	A	3/2008

OTHER PUBLICATIONS

International Search Report for PCT Application PCT/KR2009/006333. Korean Intellectual Property Office. Jun. 10, 2010.

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(57)

ABSTRACT

The present invention relates to a surgical robot system having a tool for minimally invasive surgery. More specifically, the present invention relates to a surgical robot system that helps a user such as a surgeon control the tool for minimally invasive surgery in a dexterous and convenient manner.

21 Claims, 36 Drawing Sheets

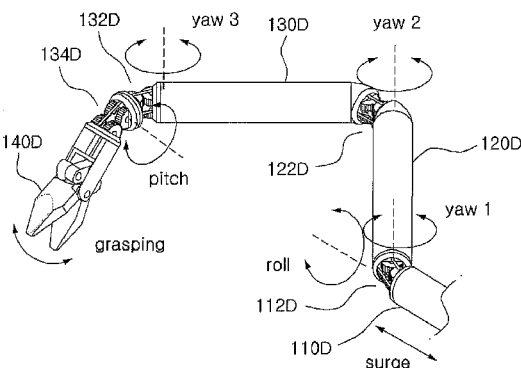
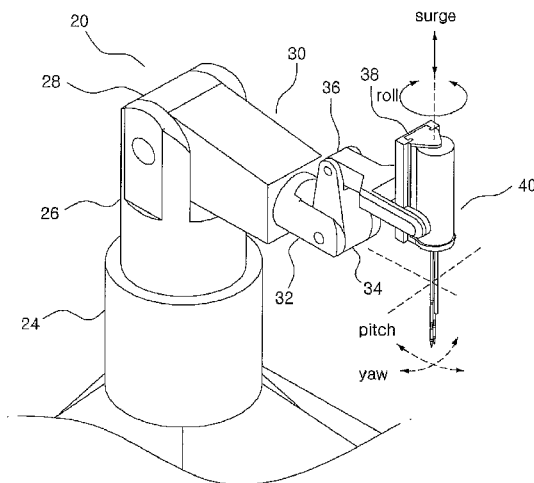


Fig. 1

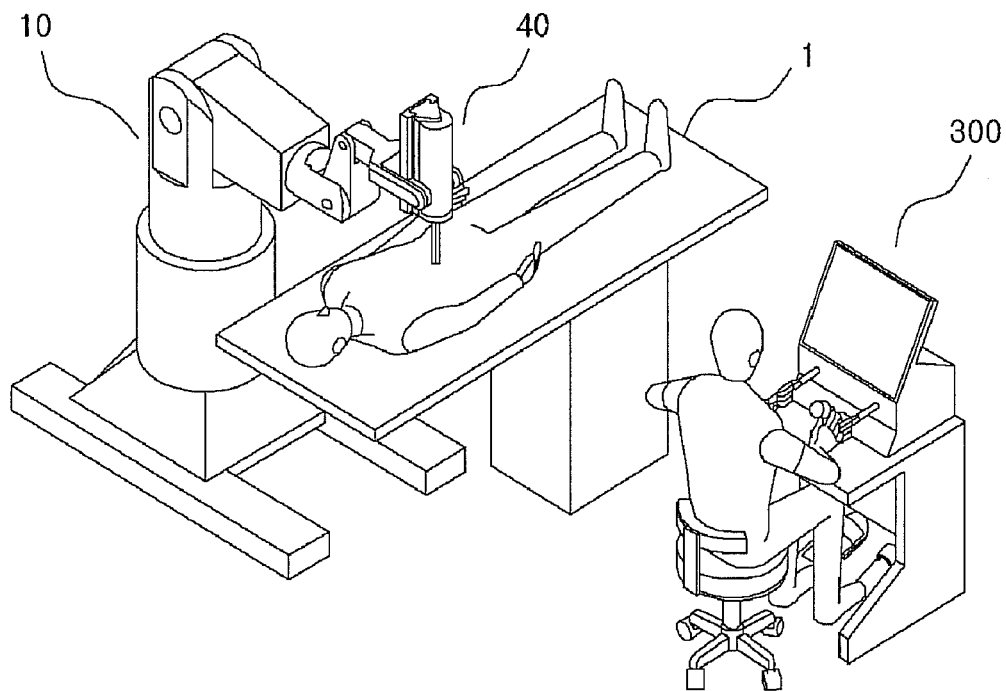


Fig. 2

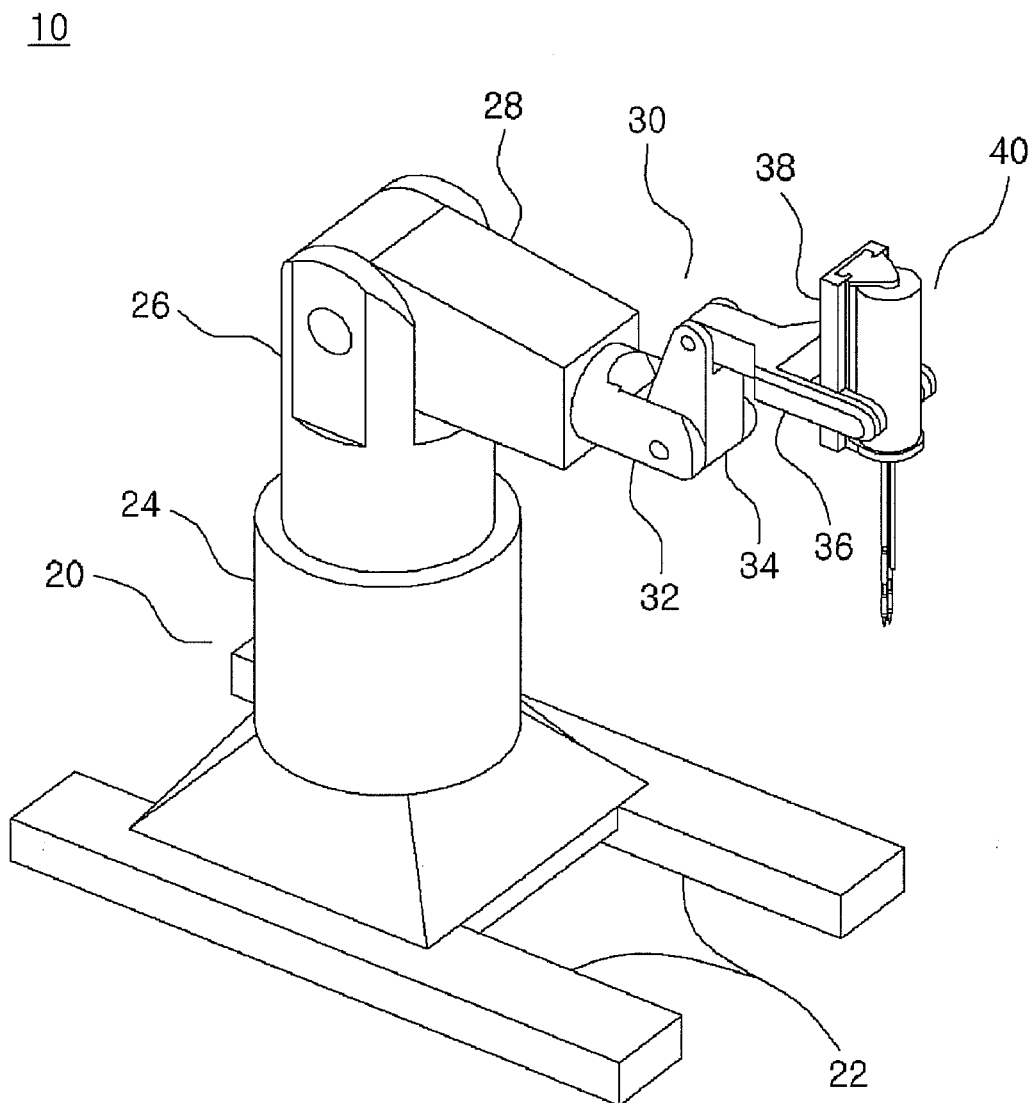


Fig. 3

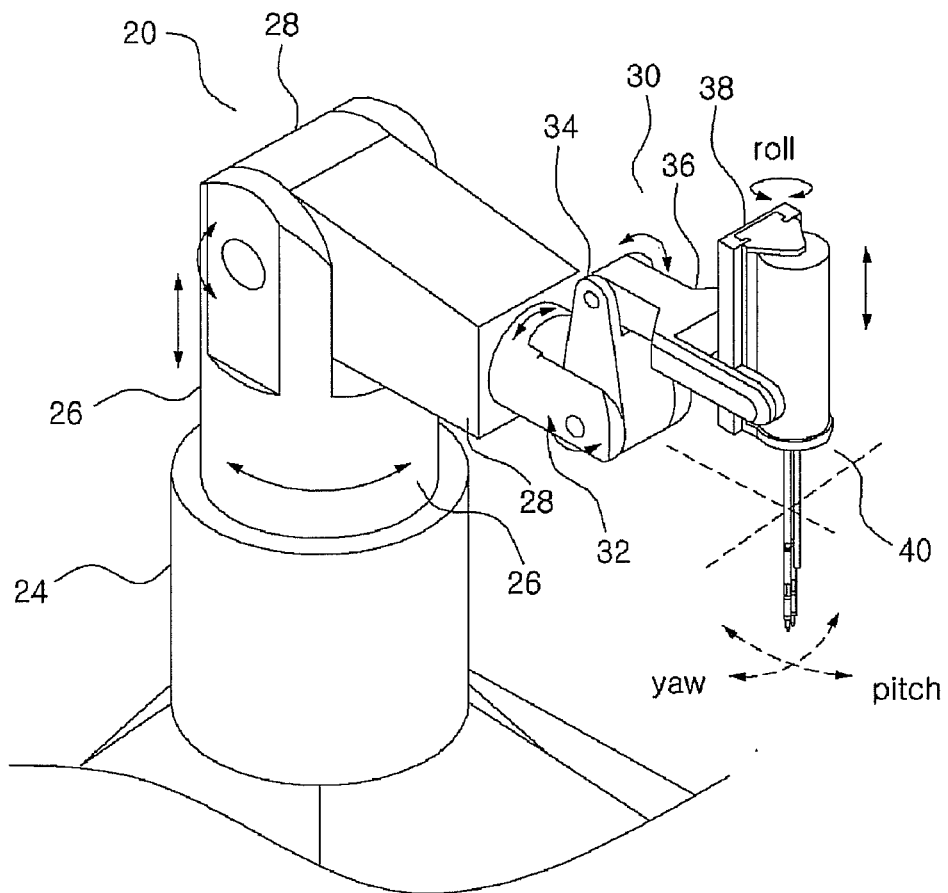


Fig. 4

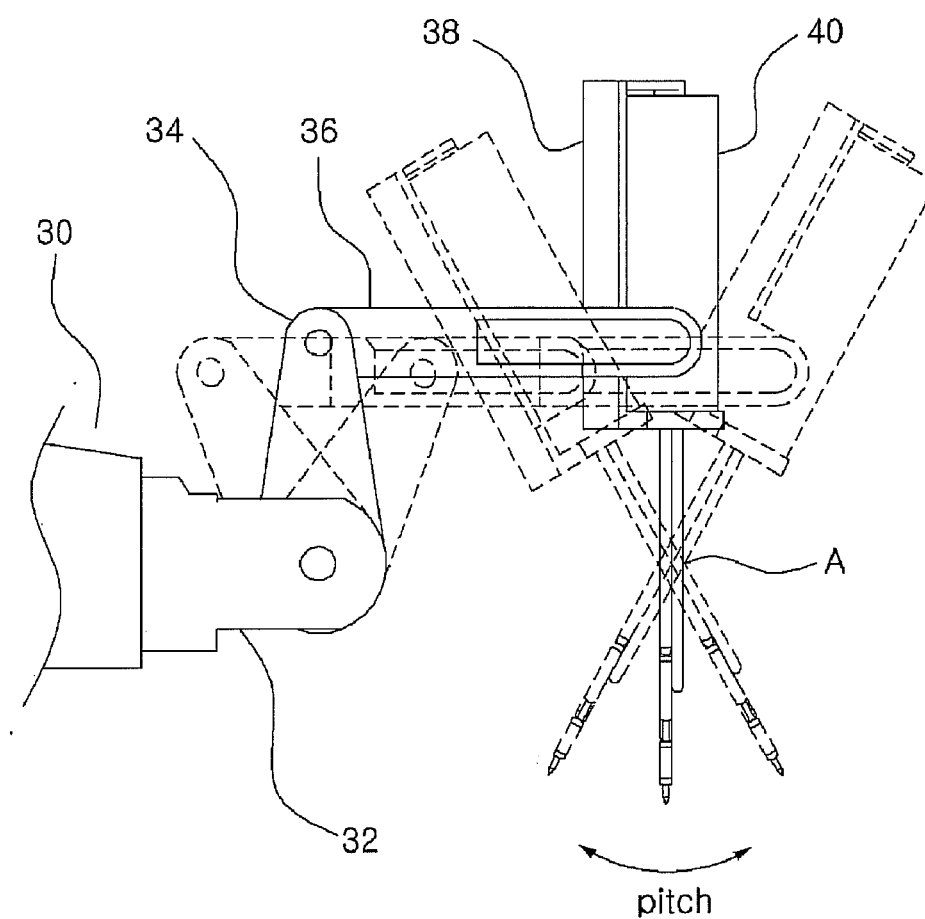


Fig. 5

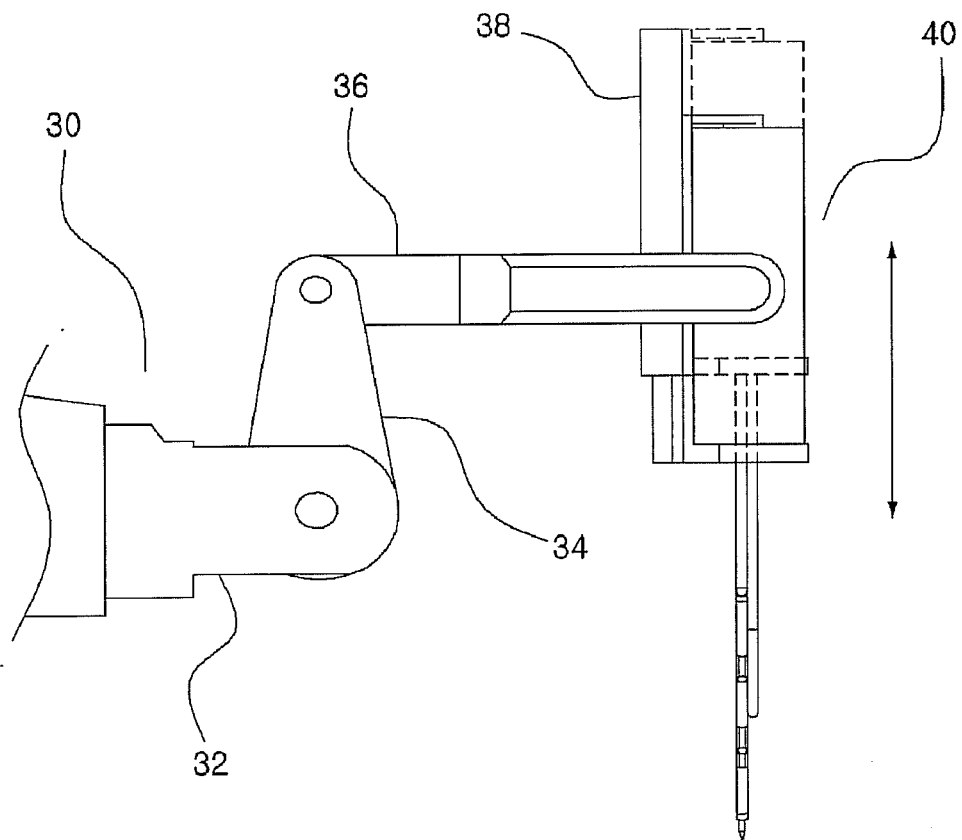


Fig. 6

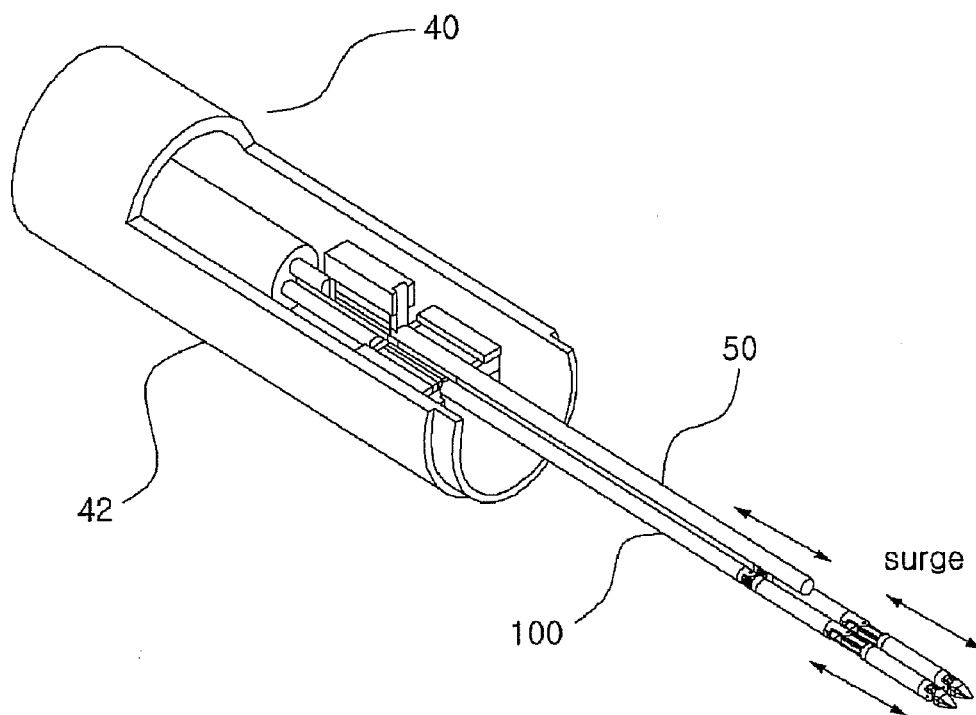


Fig. 7

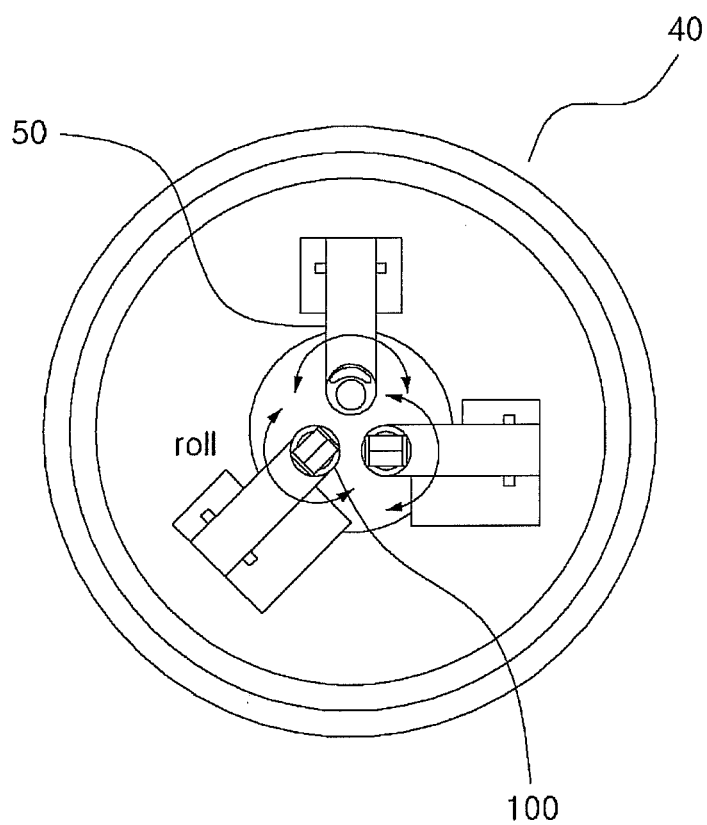


Fig. 8

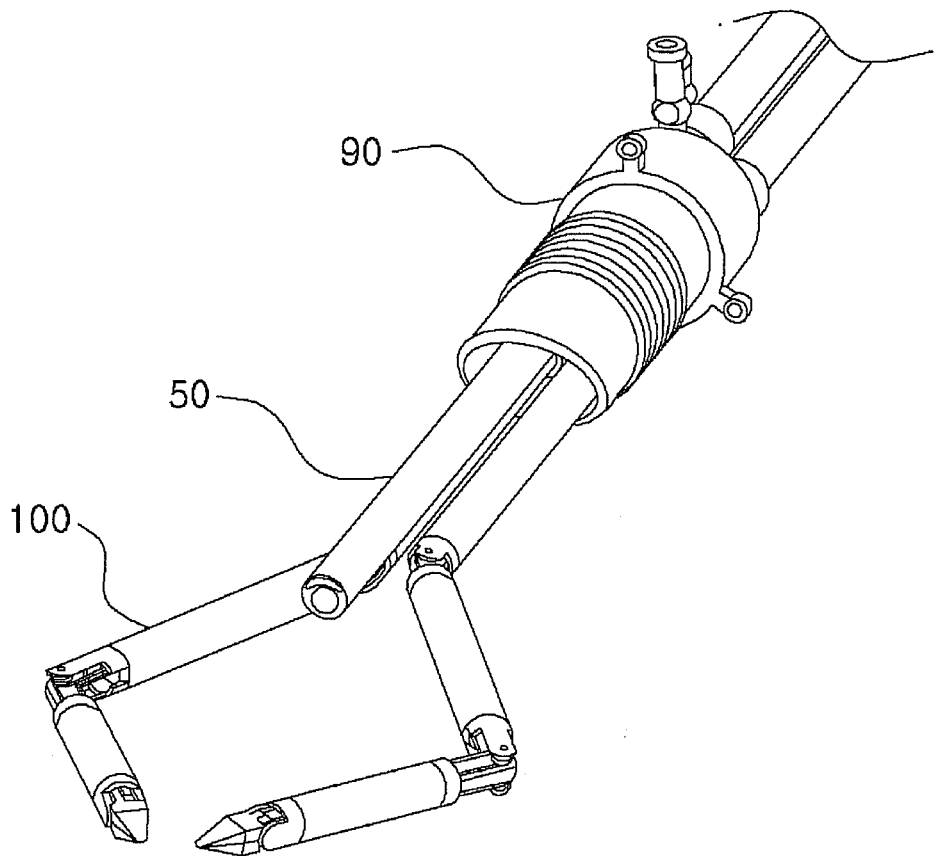


Fig. 9

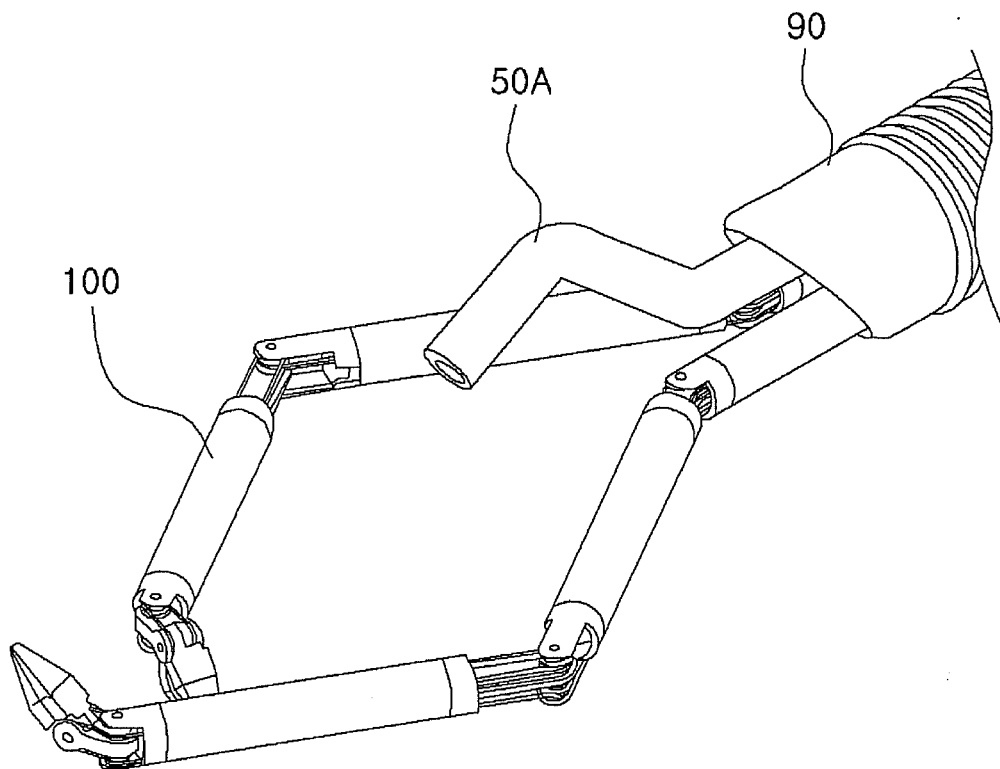


Fig. 10

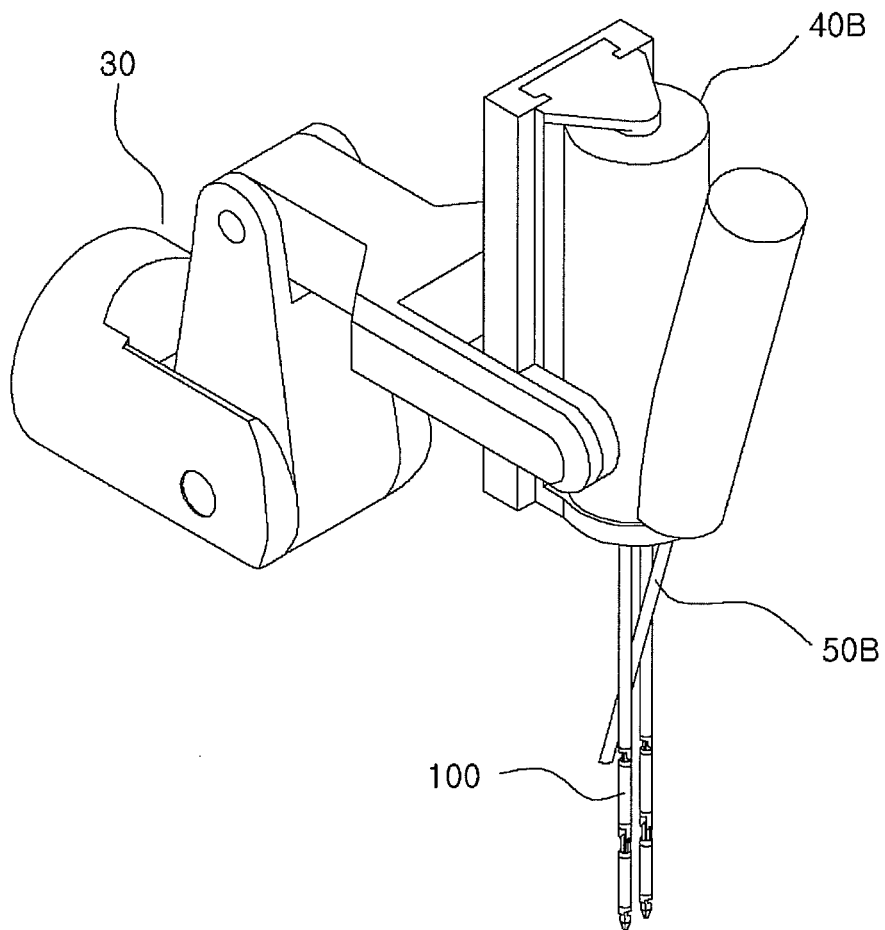


Fig. 11

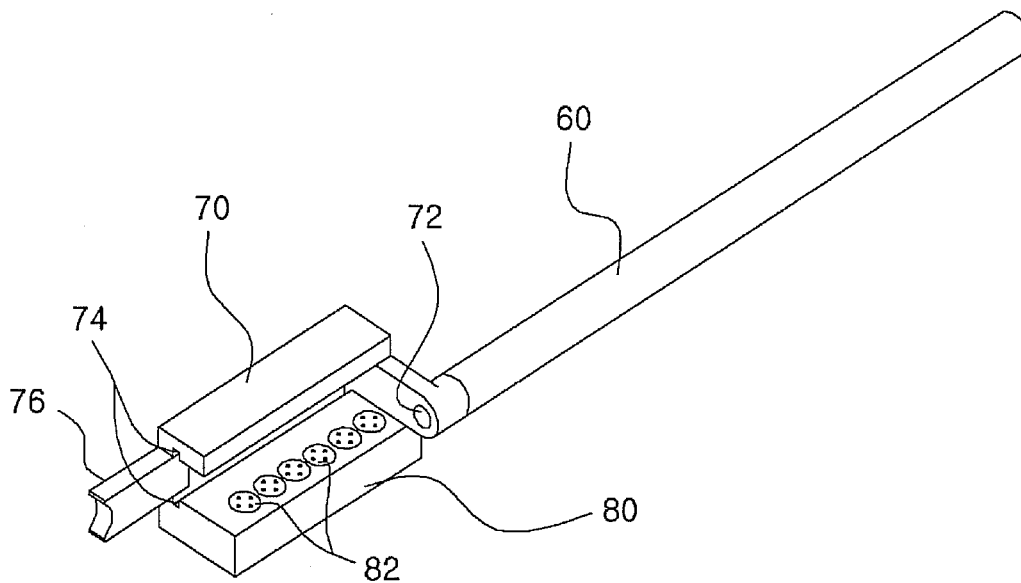


Fig. 12

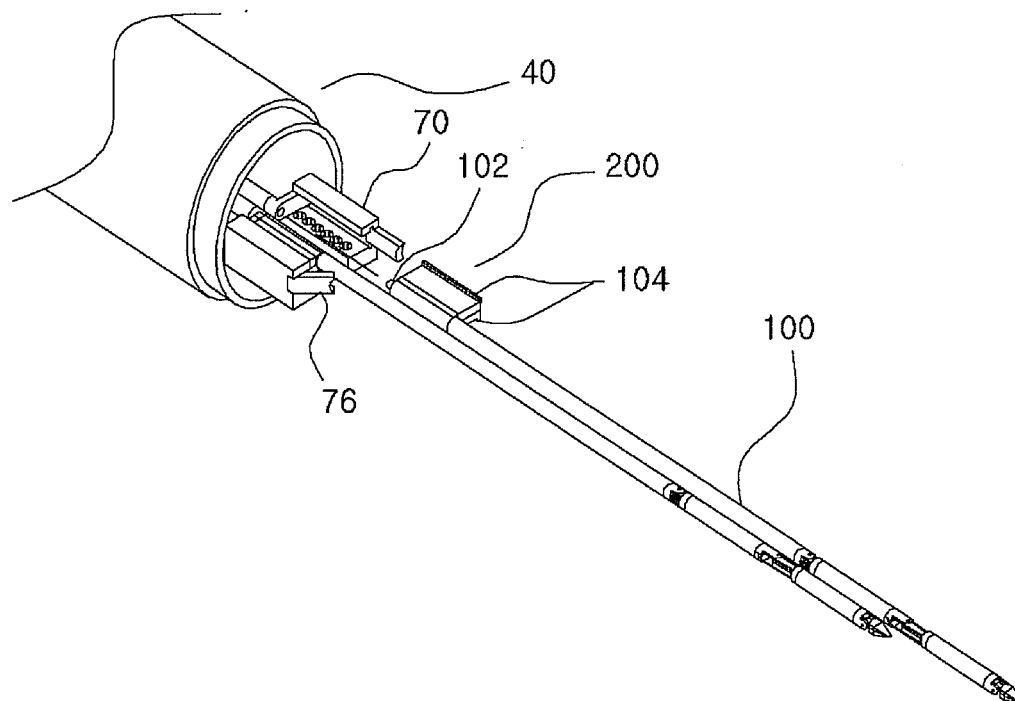


Fig. 13

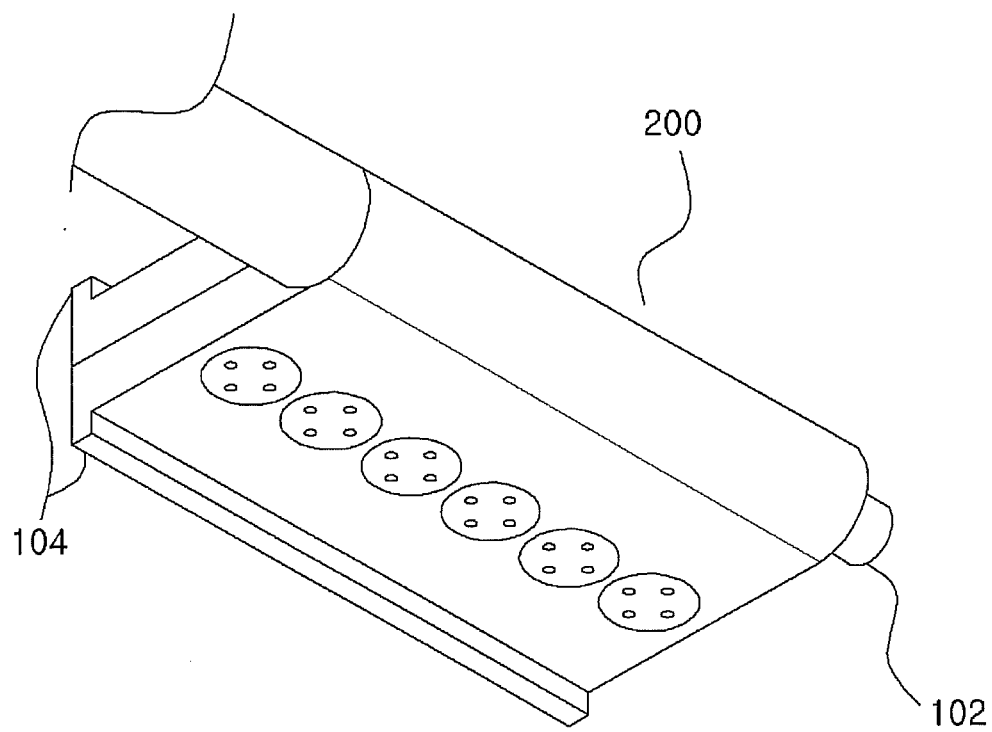


Fig. 14

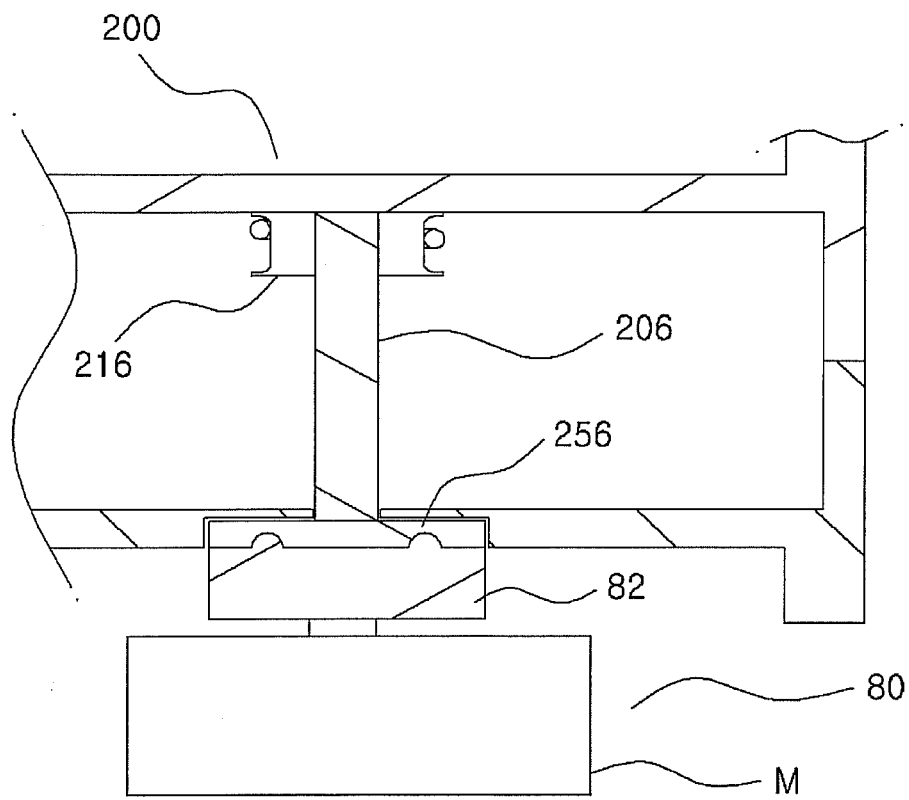


Fig. 15

100

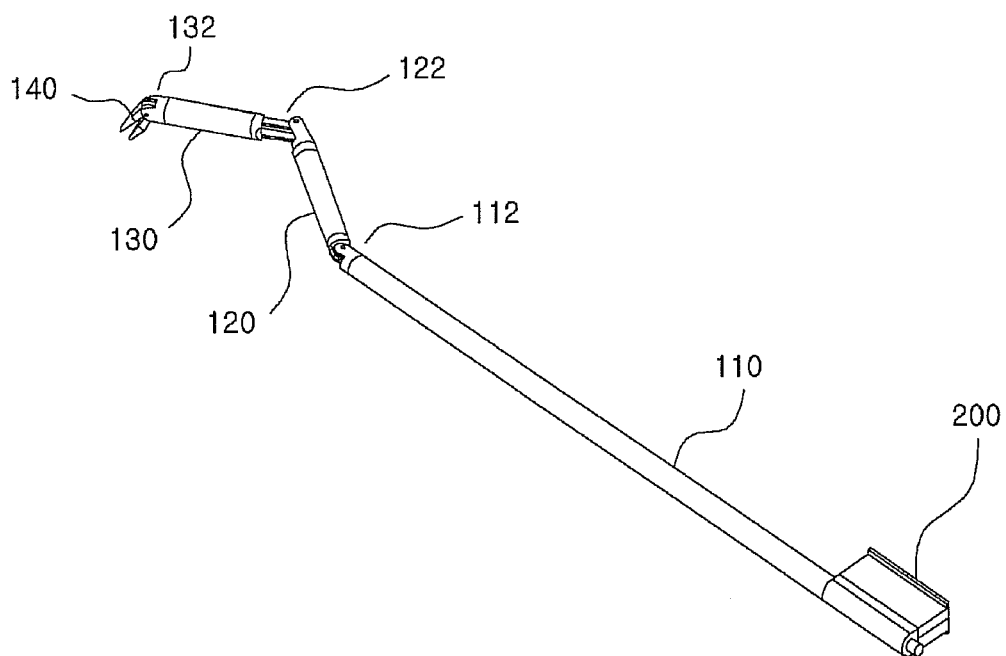


Fig. 16

200

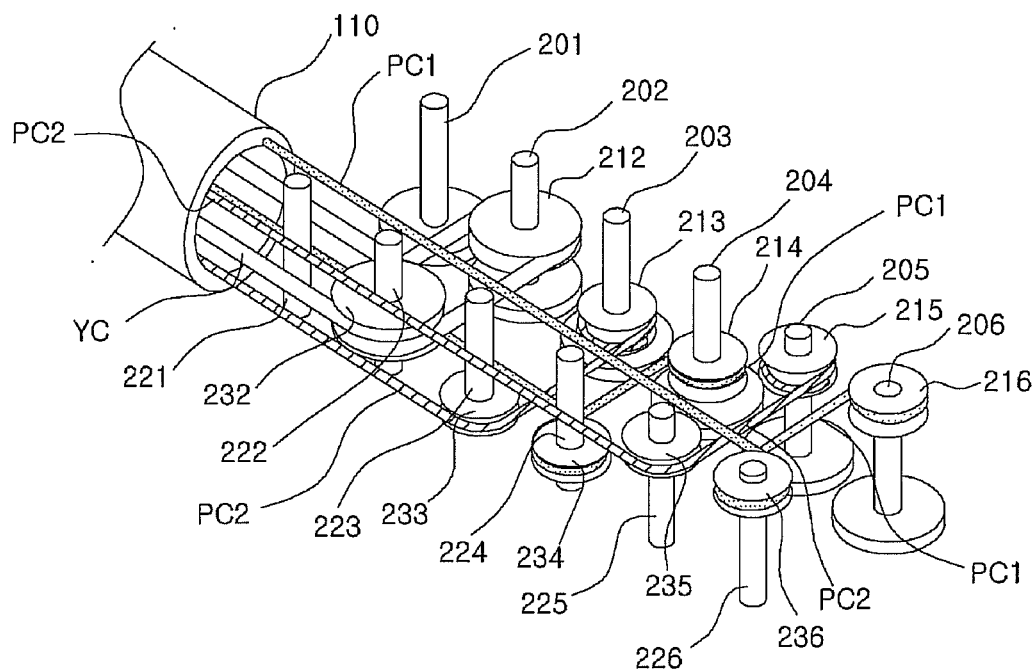


Fig. 17

200

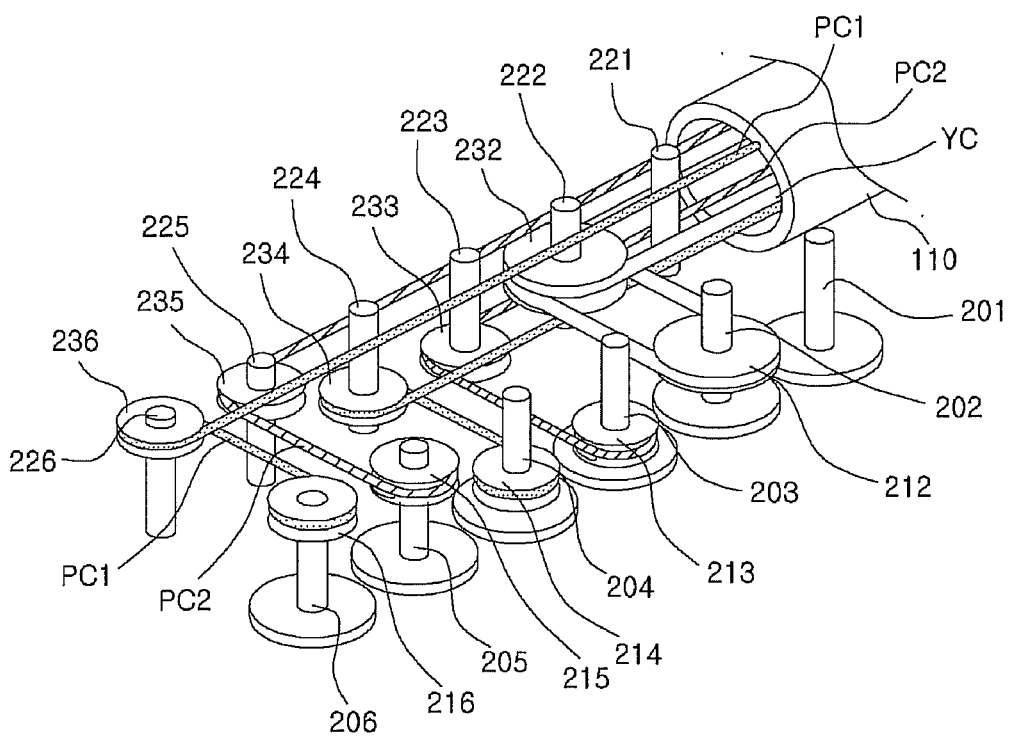


Fig. 18

100A

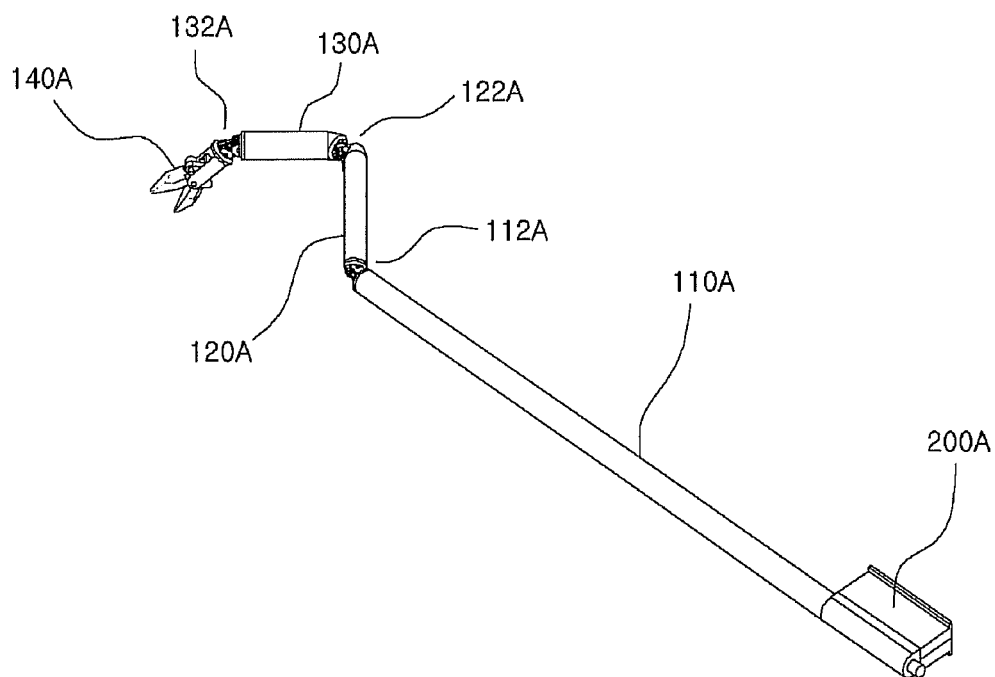


Fig. 19

200A

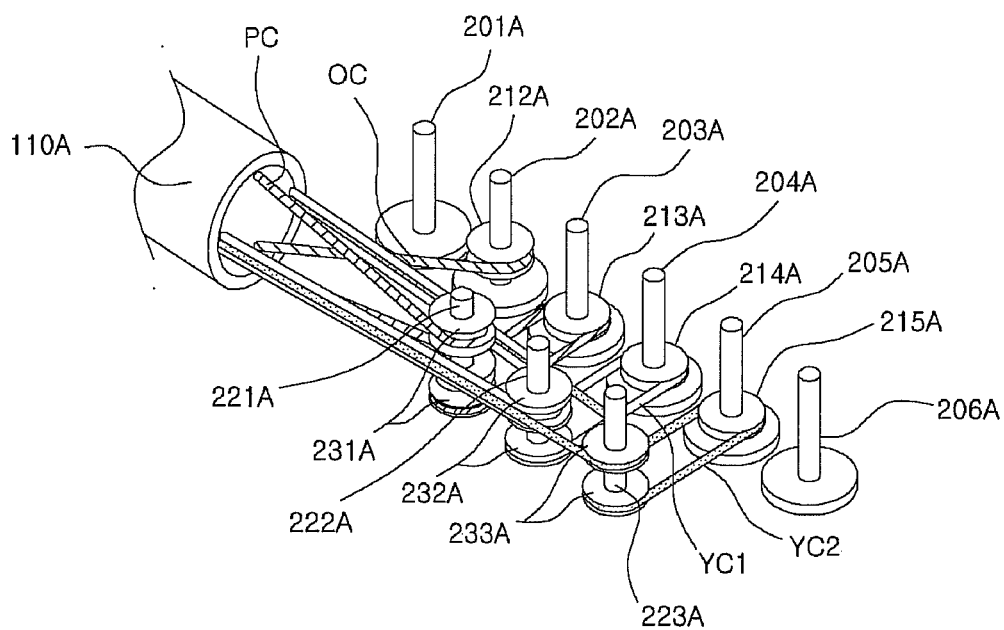


Fig. 20

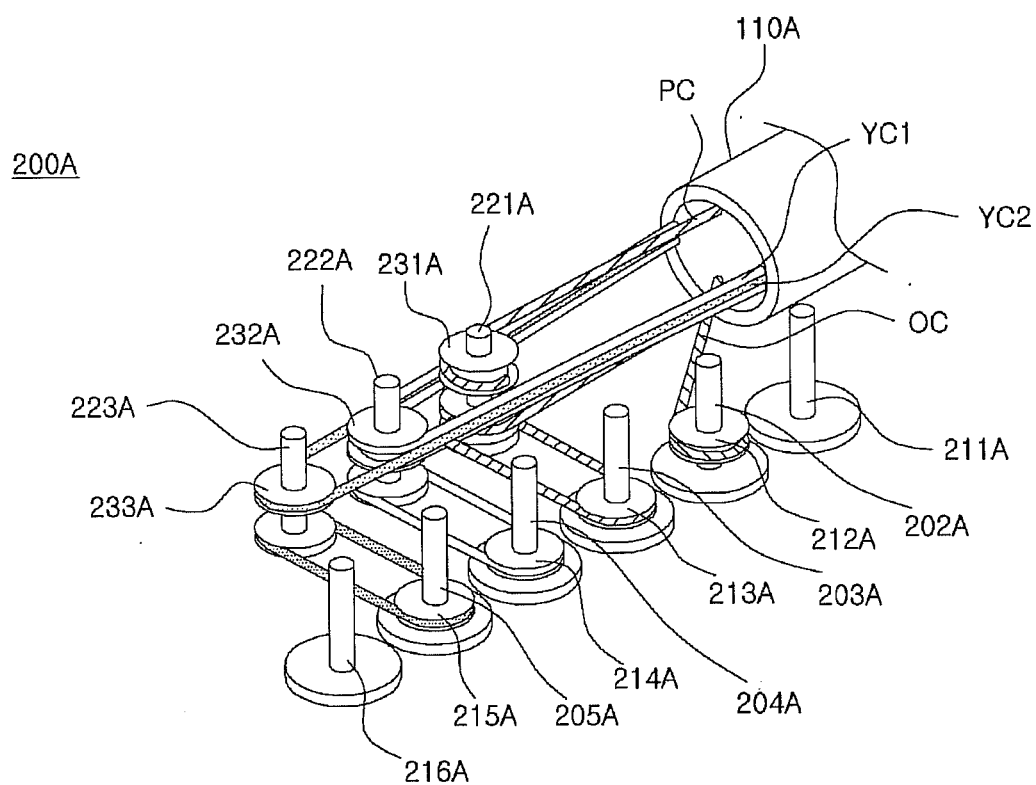


Fig. 21

200A

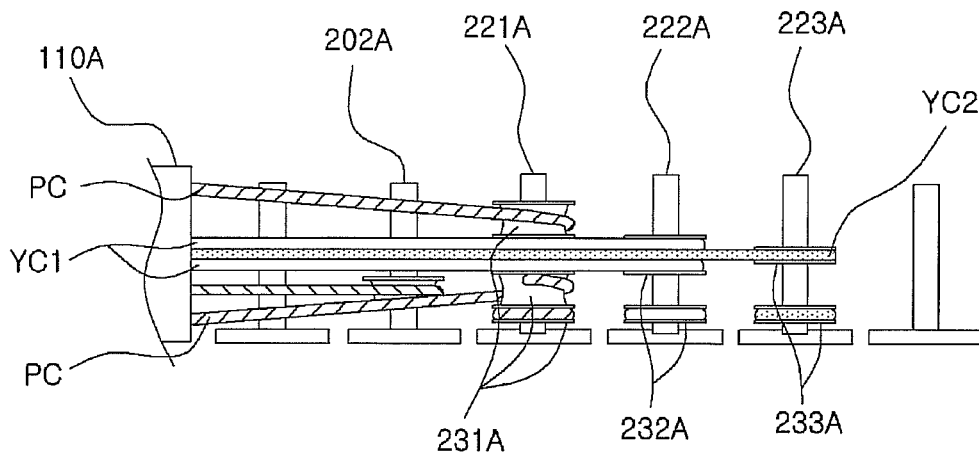


Fig. 22

100B

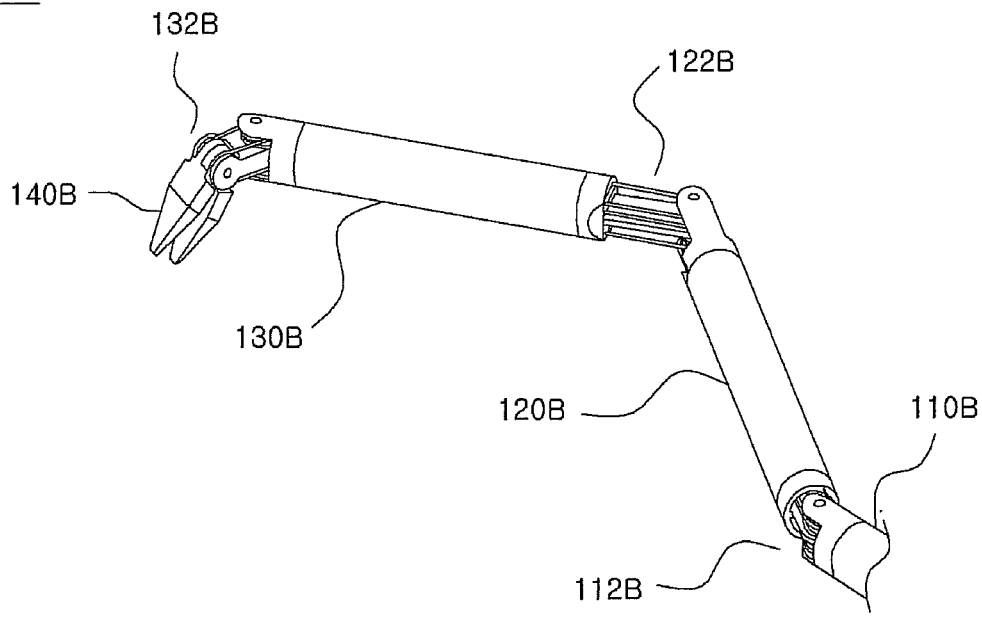


Fig. 23

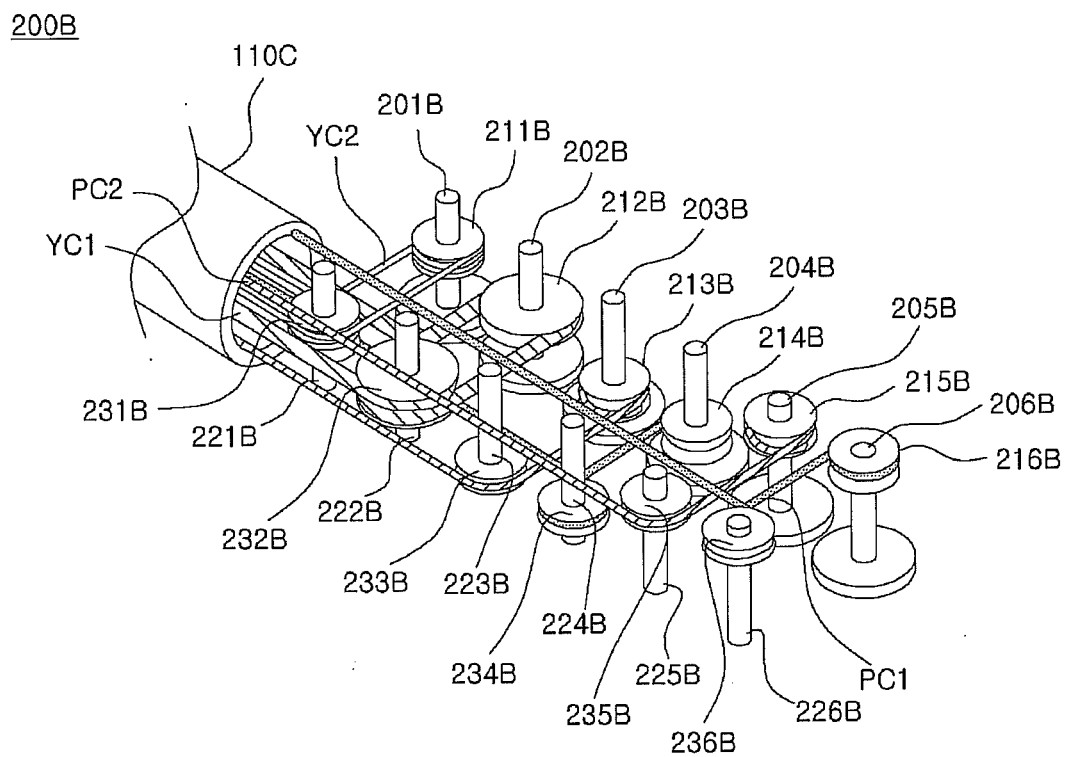


Fig. 24

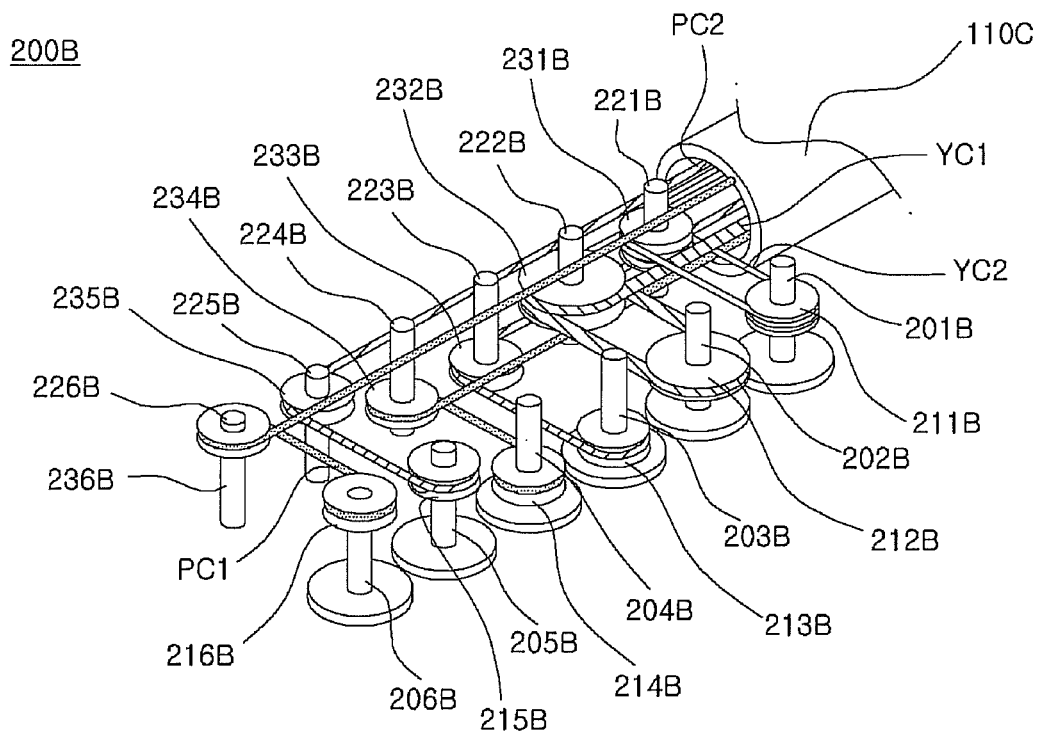


Fig. 25

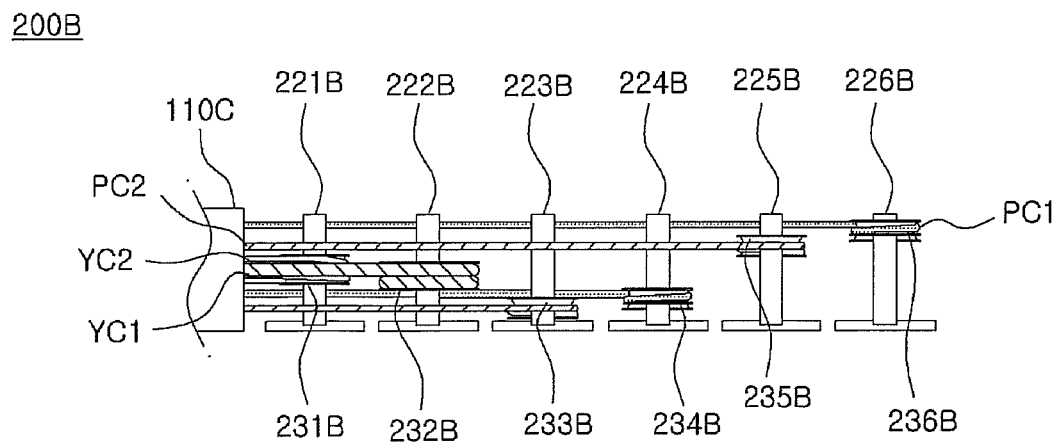


Fig. 26

100C

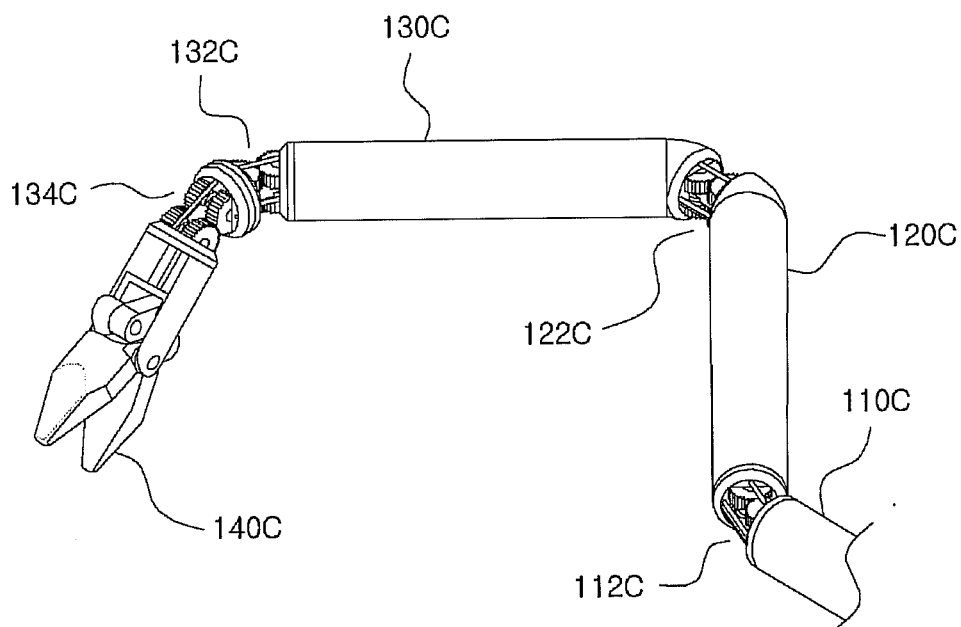


Fig. 27

200C

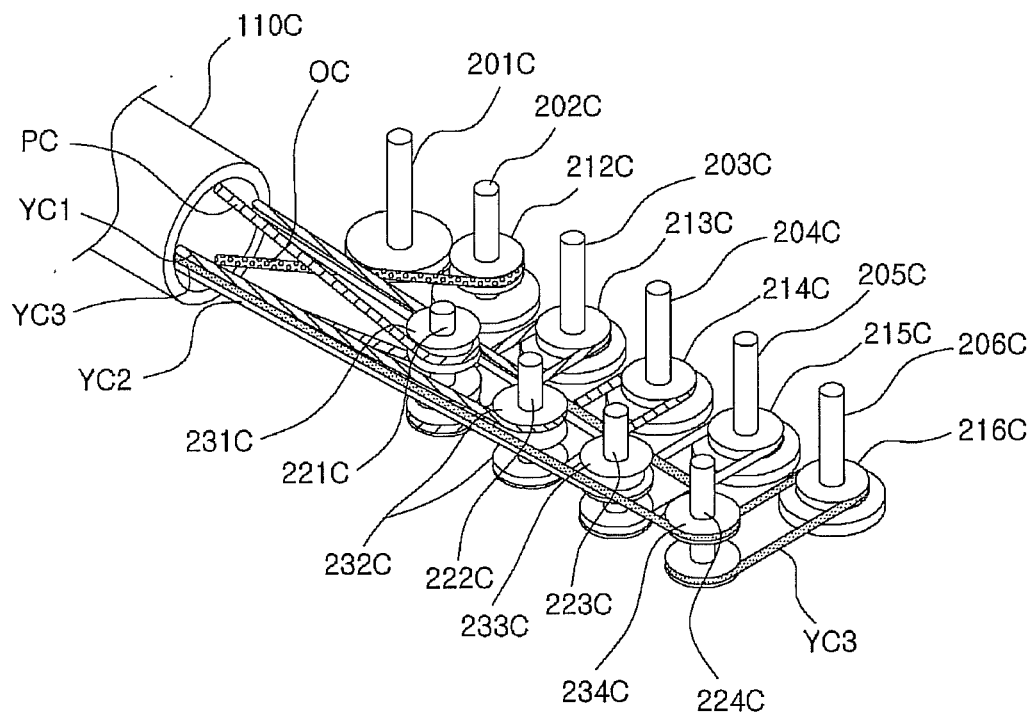


Fig. 28

200C

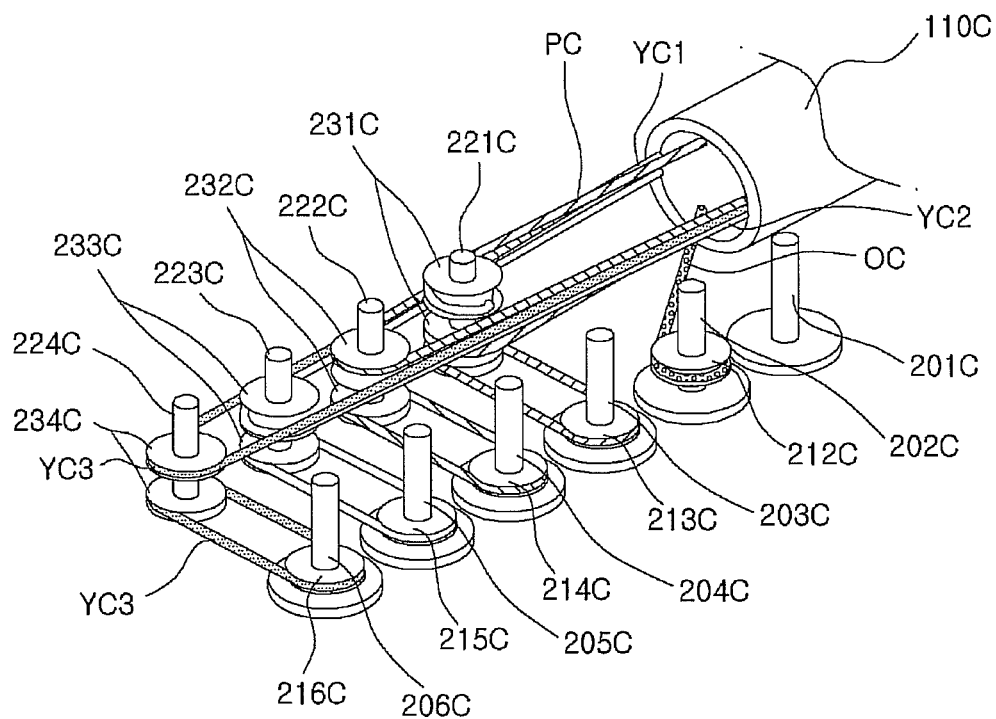


Fig. 29

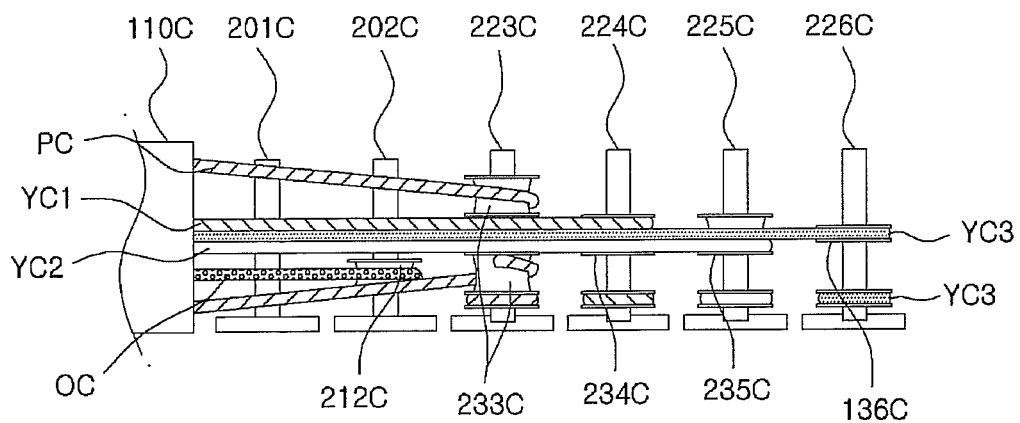
200C

Fig. 30

100D

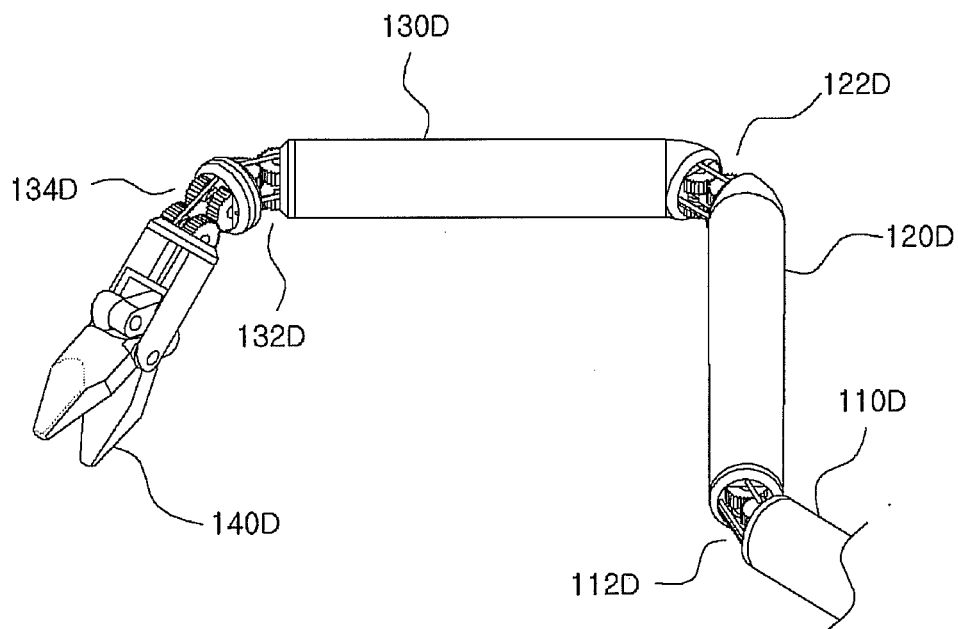


Fig. 31

200D

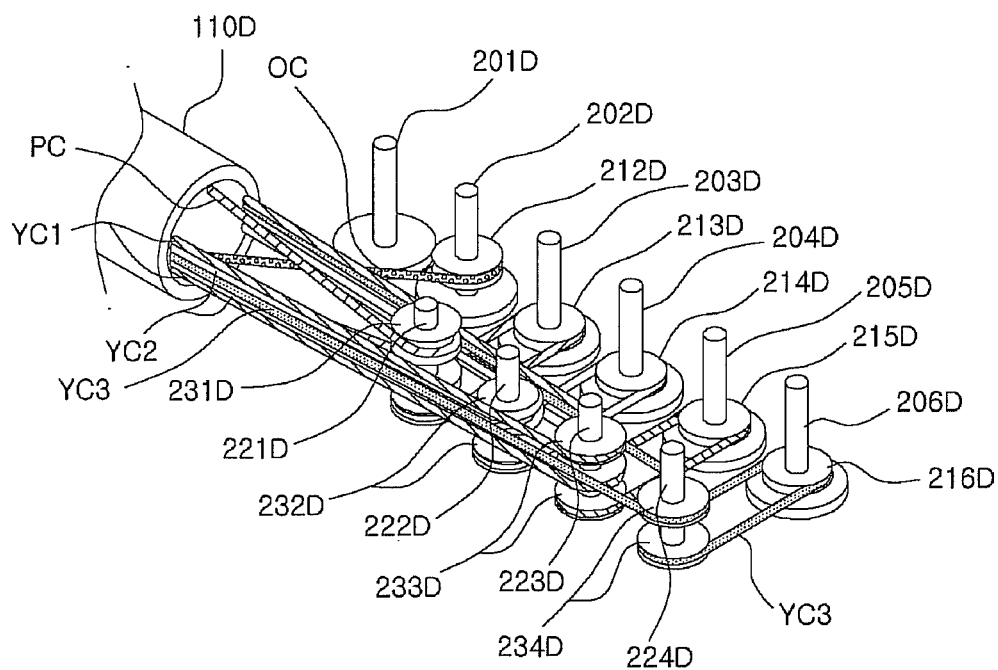


Fig. 32

200D

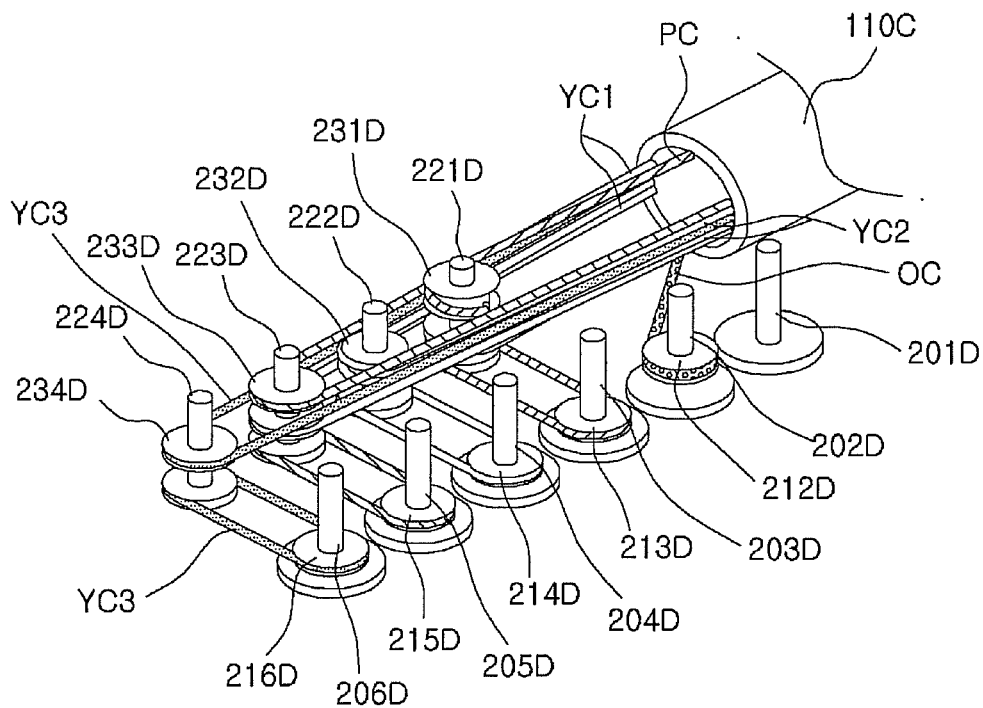


Fig. 33

200D

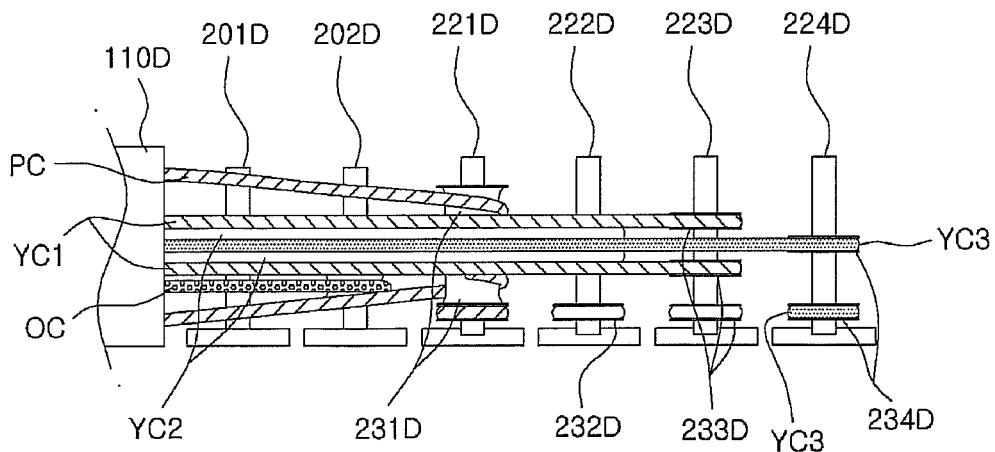


Fig. 34

100E

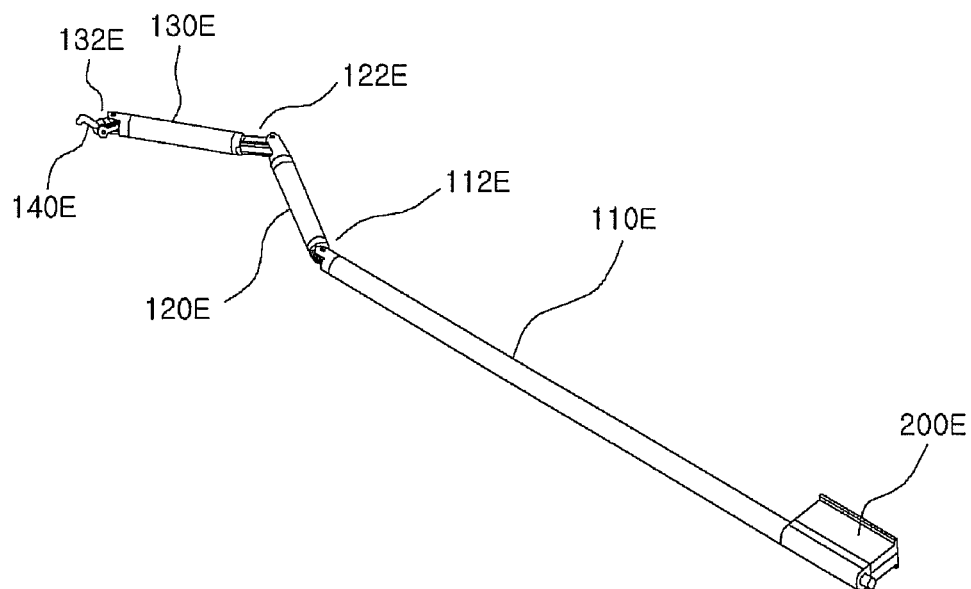


Fig. 35

100F

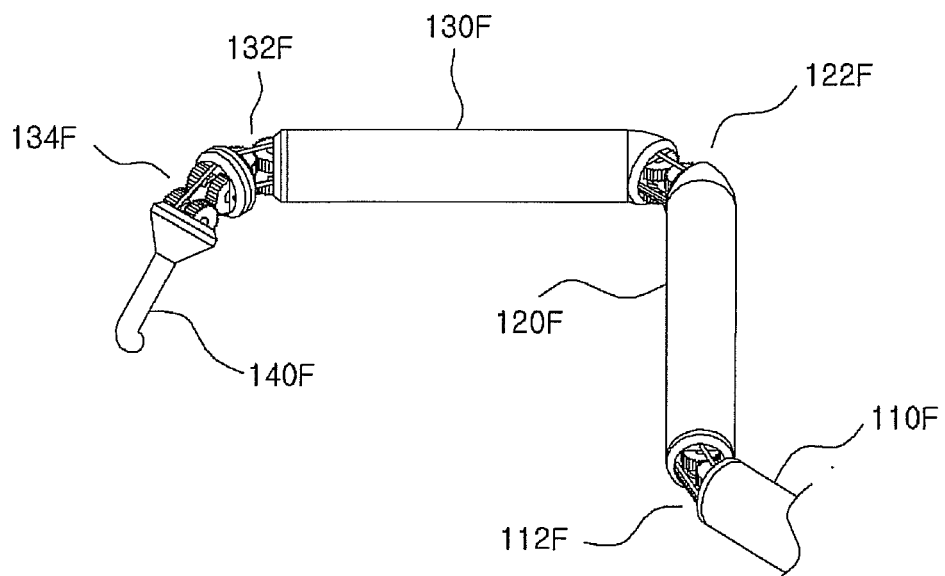


Fig. 36

300

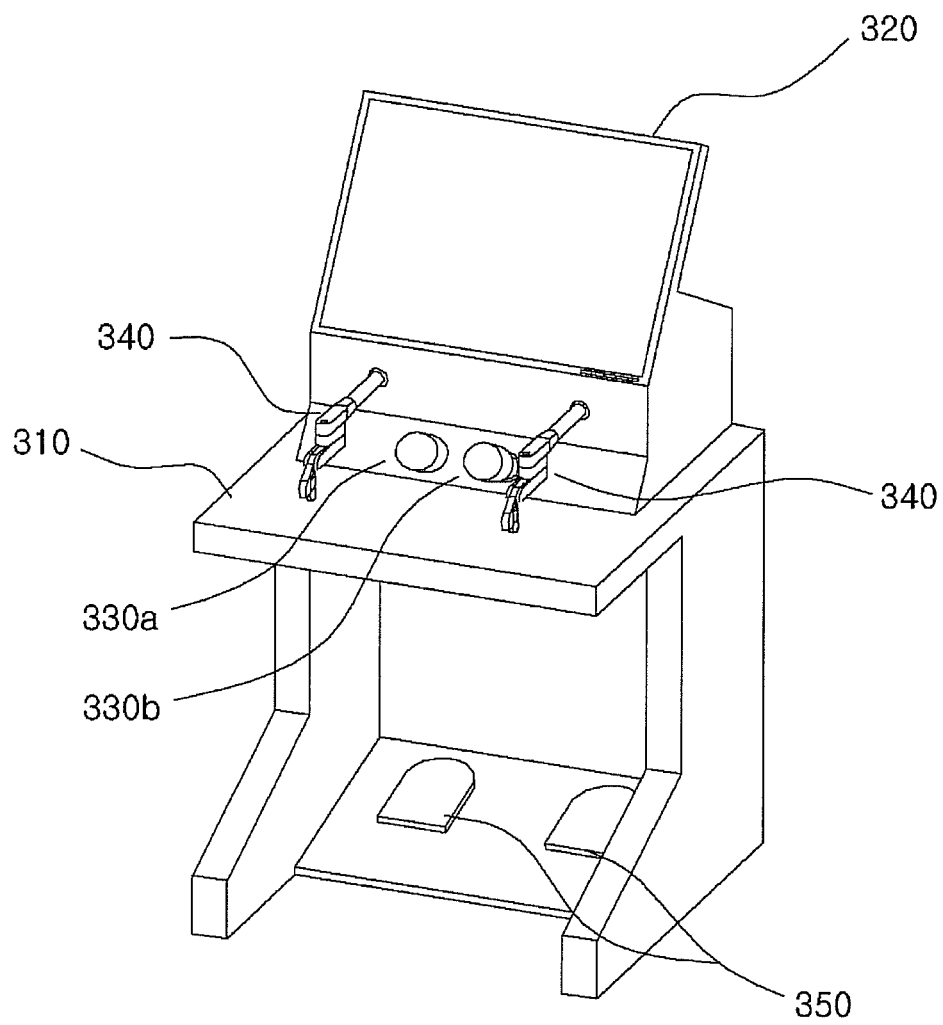


Fig. 37

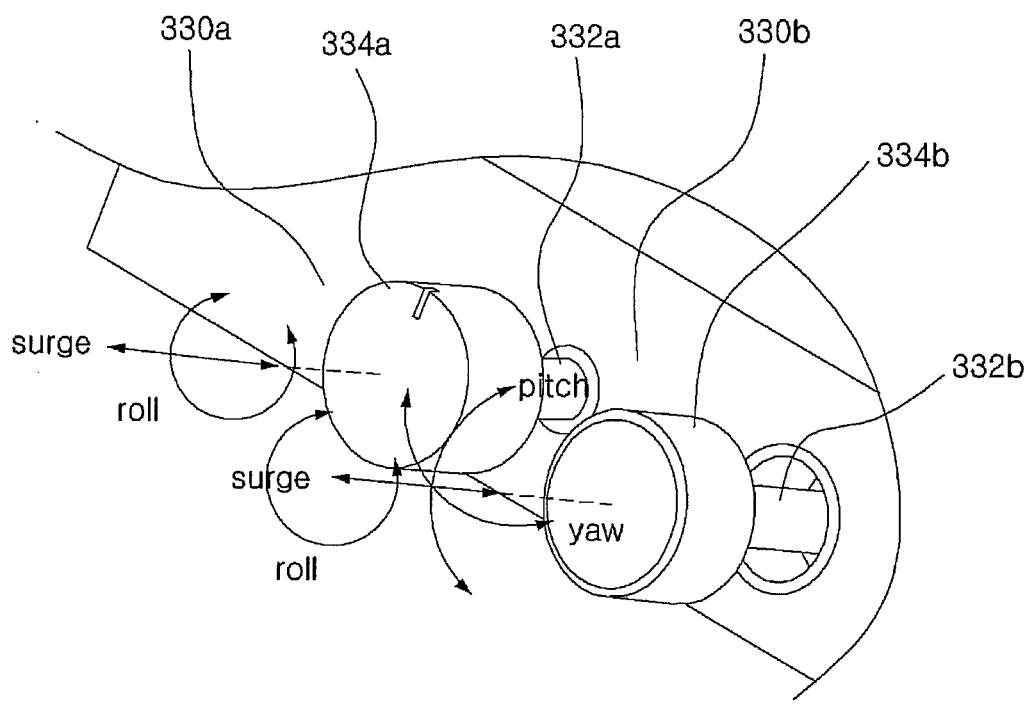


Fig. 38

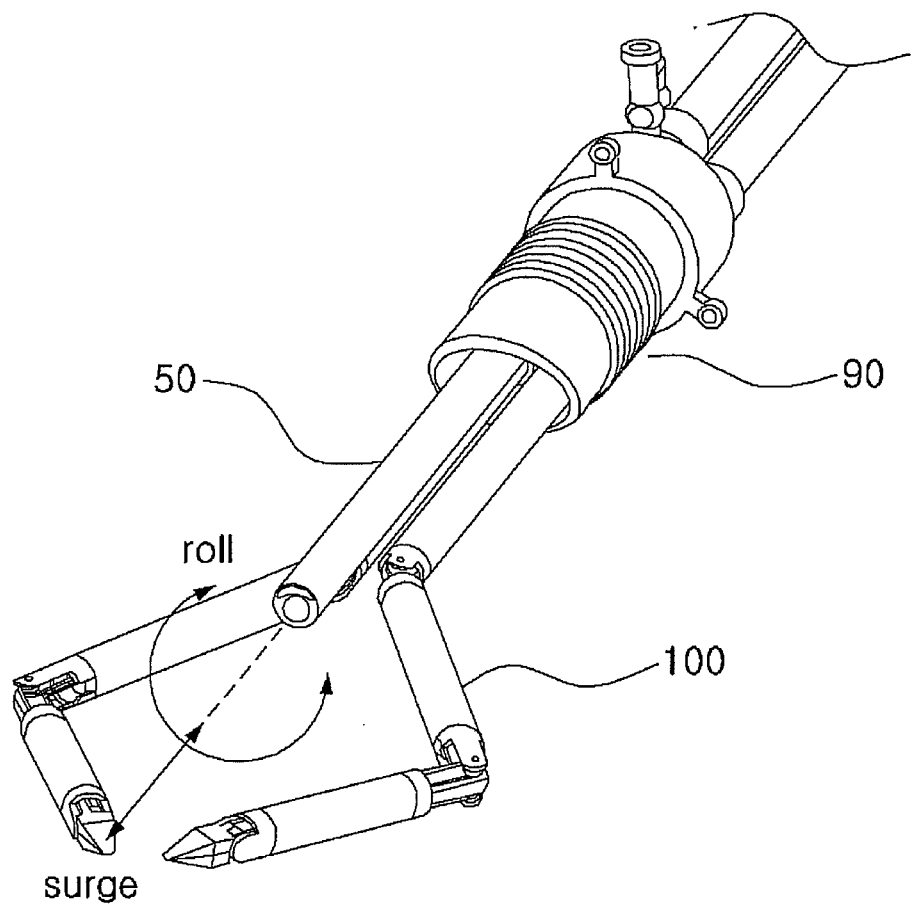


Fig. 39

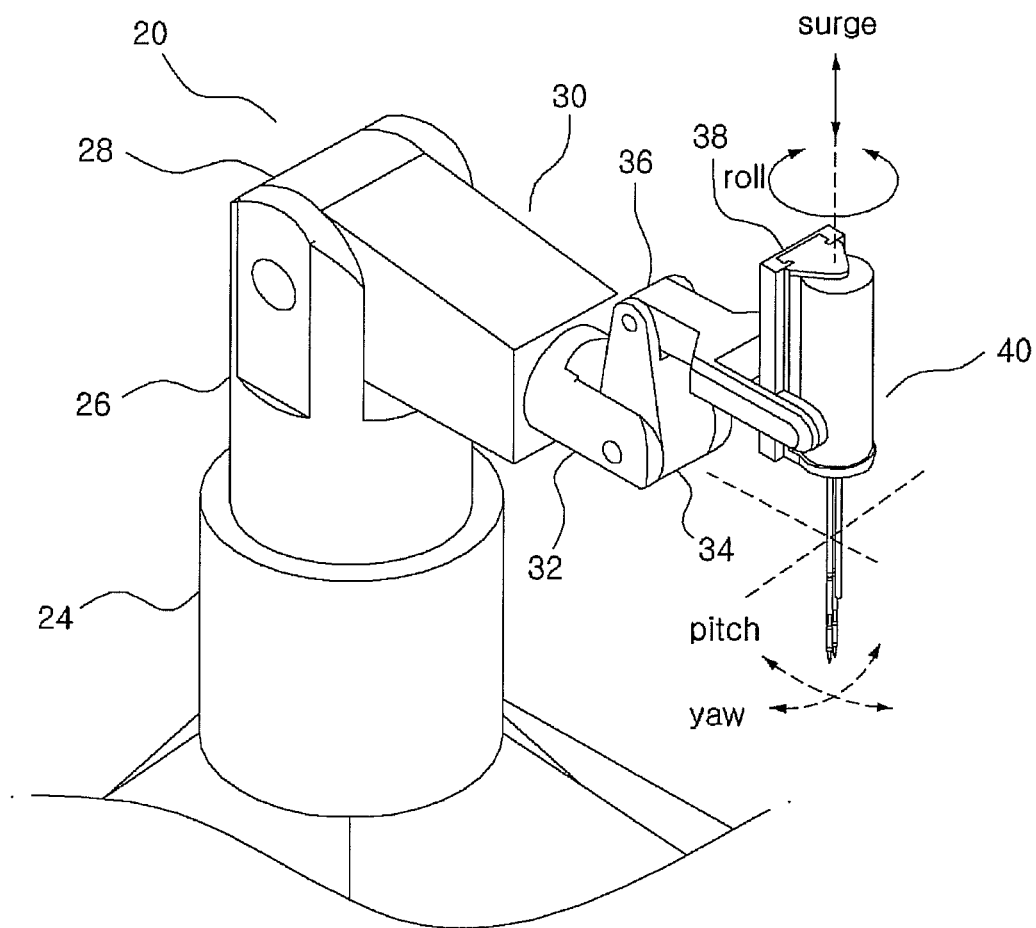


Fig. 40

340

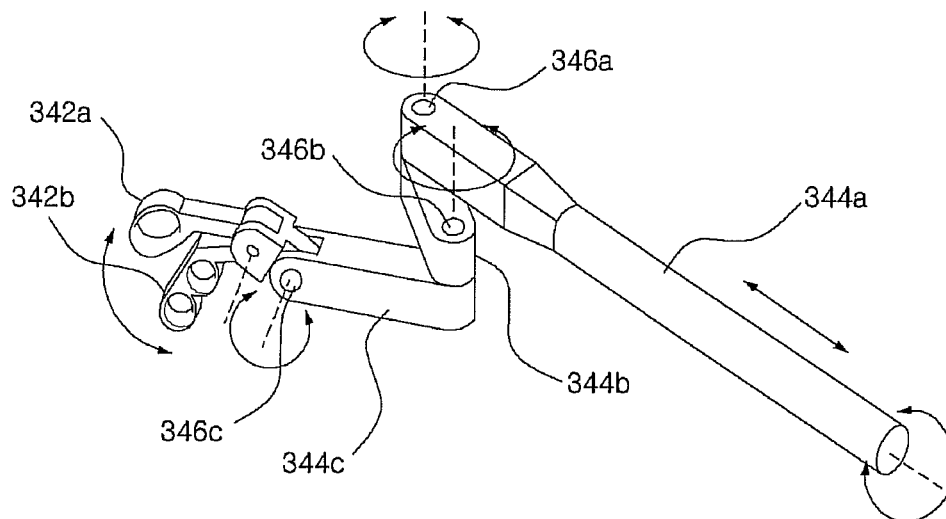


Fig. 41

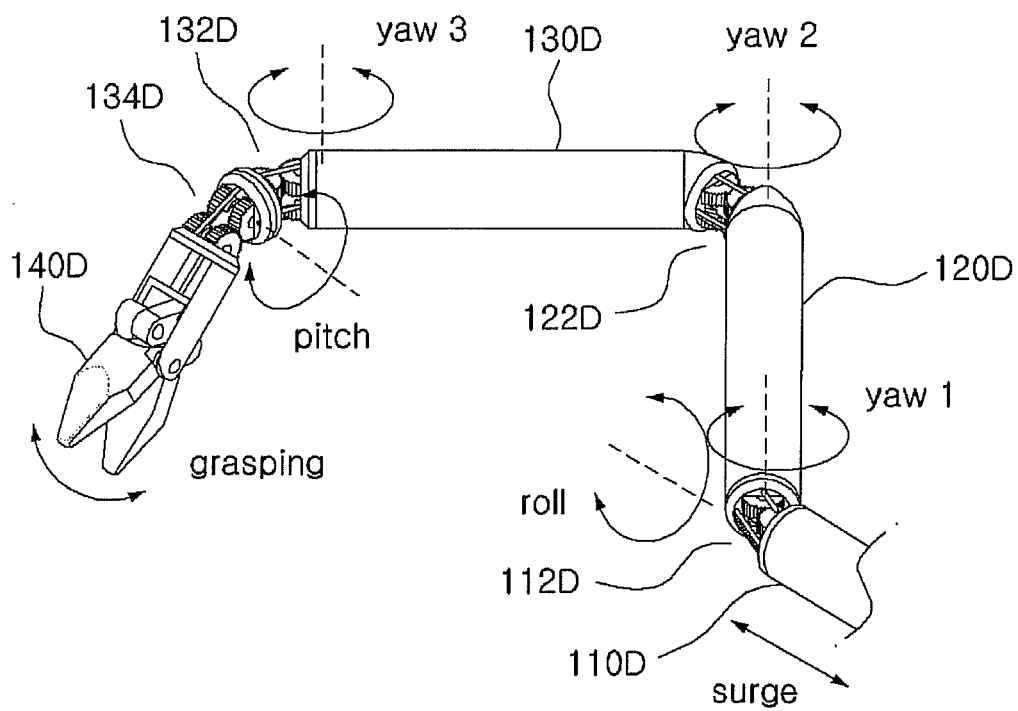


Fig. 42

100B

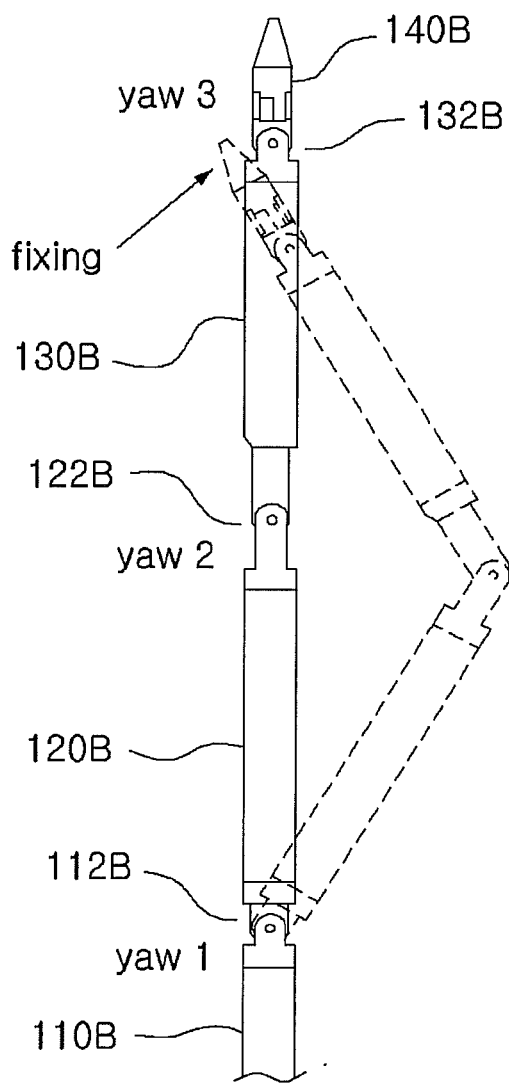
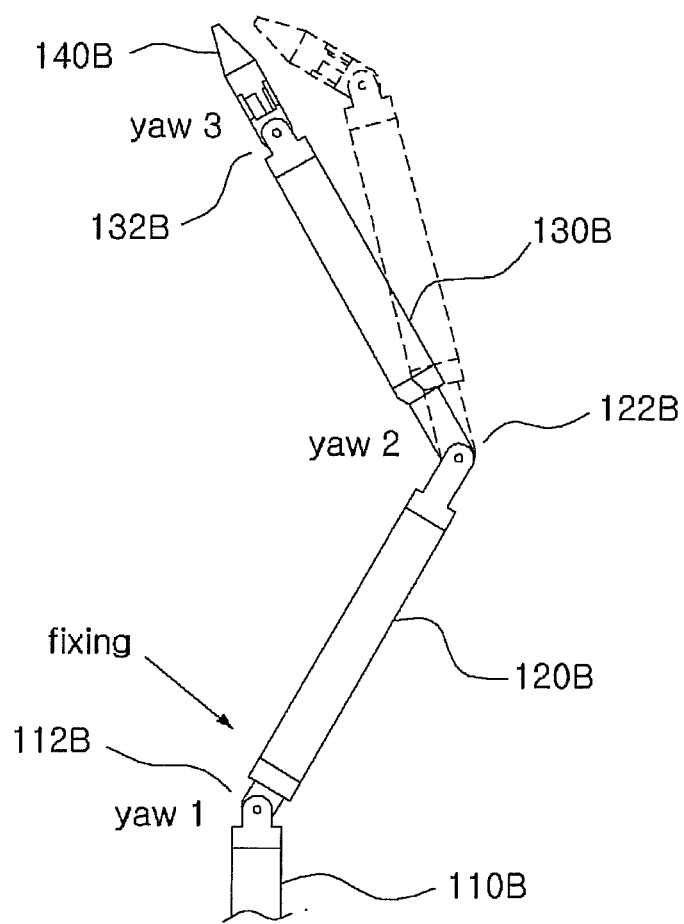


Fig. 43

100B



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SURGICAL ROBOT SYSTEM HAVING TOOL FOR MINIMALLY INVASIVE SURGERY

PRIORITY

The present application claims priority under 35 U.S.C. §371 to PCT Application PCT/KR2009/006333, filed on Oct. 30, 2009, which claims priority to Korean Patent Application No. 10-2008-0108103, filed on Oct. 31, 2008, the disclosures of which are hereby incorporated by reference in their entireties.

FIELD OF THE INVENTION

The present invention relates to a surgical robot system having a tool for minimally invasive surgery. More specifically, the present invention relates to a surgical robot system that helps a user such as a surgeon control the tool for minimally invasive surgery in a dexterous and convenient manner.

BACKGROUND OF THE INVENTION

Minimally invasive surgery is a surgical approach that involves use of instruments inserted through several tiny incision openings to perform a surgery causing minimal tissue trauma.

This minimally invasive surgery relatively reduces changes in metabolism of the patient in the period of post-surgical care, so it is beneficial to rapid recovery of the patient. Therefore, using such minimally invasive surgery shortens length of a hospital stay of the patient after the surgery and allows patients to return to normal physical activities more quickly. In addition, minimally invasive surgery causes less pain and reduces scar to patients after surgery.

The most general form of the minimally invasive surgery is endoscopy. Among them, a laparoscopy that involves minimally-invasive inspection and operation inside abdominal cavity is known as the most general form of endoscopy. To operate the standard laparoscopic surgery, an abdomen of the patient is insufflated with gas, and small incisions (about ½ inch or less) are formed for use as an entrance of a tool for the laparoscopic surgery, through which a trocar is inserted. In general, laparoscopic surgical tools include a laparoscope (for observation of a surgical site) and other working tools. Here, the working tools are similar in structure to the conventional tools used for small incision surgery, except that the end effector or working end of each tool is separated from its handle by an elongated shaft. For instance, working tools may include a clamp, a grasper, scissors, a stapler, needle holder, and so forth. To perform the surgery, a user, such as a surgeon, puts the working tool into a surgical site through the trocar, and manipulates it from the outside of abdominal cavity. Then, the surgeon monitors the procedure of the surgery through a monitor that displays the image of the surgical site that is taken by the laparoscope. The endoscopic approach similar to this is broadly used in retroperitoneoscopy, pelviscopy, arthroscopy, cisternoscopia, sinuscopy, hysteroscopy, nephroscopy, cystoscopy, urethroscopy, pyeloscopy, and so on.

Although this minimally invasive surgery has a number of advantages, it has shortcomings in the difficulty of approaching the conventional minimally invasive surgical tools to a surgical site and the inconvenient or complicate manipulation of such tools because of an end effector connected to a rigid and long shaft. As attempts to solve the above problems, the present inventor has devised a novel tool for minimally inva-

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sive surgery as described in Korean Patent Application Nos. 2008-51248, 2008-61894, 2008-79126 and 2008-90560 filed prior to this application, the contents of which are herein incorporated by reference in their entirety.

In particular, among these applications, the minimally invasive surgical tools disclosed in Korean Patent Application Nos. 2008-79126 and 2008-90560 are very useful in a case where only a single incision is formed in a patient's body to perform surgery. Accordingly, the inventor devised a surgical robot system having a tool for minimally invasive surgery described in at least one of the prior applications or a surgical robotic system which adopts the principles of the tool.

SUMMARY OF THE INVENTION

The present invention is directed to solve all of the problems mentioned above.

It is an object of the present invention to provide a surgical robot system suitable for use with a tool for carrying out a minimally invasive surgery in a dexterous and convenient manner.

Another object of the present invention is to provide a surgical robot system for enabling a user to perform remote surgery even if a patient to be operated on is far away in a physically different location.

Still another object of the present invention is to provide a surgical robot system for helping a user perform a minimally invasive surgery within a relatively short period of time using relatively low energy.

In accordance with one aspect of the present invention, there is provided a Surgical robot system comprising, a plurality of robot arms, and a surgery actuator, wherein the surgery actuator is controlled in a pitch direction and/or in a yaw direction by at least one of the plurality of robot arms, wherein the surgery actuator comprises at least one tool for minimally invasive surgery, wherein the at least one tool for minimally invasive surgery comprises a main shaft, a first actuating shaft, a second actuating shaft, an end effector and a handling part, and wherein the handling part controls the first actuating shaft, the second actuating shaft and the end effector.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other objects and features of the present invention will become apparent from the following description of preferred embodiments, given in conjunction with the accompanying drawings, in which:

FIG. 1 shows an overall configuration of a surgical robot system in accordance with one embodiment of the present invention;

FIG. 2 is a perspective view showing an overall configuration of an actuation robot included in the surgical robot system in accordance with one embodiment of the present invention;

FIGS. 3 and 4 show the configuration and operations of robot arms in accordance with one embodiment of the present invention;

FIG. 5 shows that a surgery actuator in accordance with one embodiment of the present invention operates in a surge direction in parallel to the vertical axis of a fourth robot arm;

FIGS. 6 and 7 show a detailed configuration of the surgery actuator in accordance with one embodiment of the present invention and actuations of an endoscope and a tool for minimally invasive surgery with respect to the surgery actuator thereof;

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FIGS. 8 and 9 show examples where the endoscope and the tool for minimally invasive surgery in accordance with one embodiment of the present invention are formed in a bundle;

FIG. 10 shows an example of how the endoscope in accordance with one embodiment of the present invention is positioned;

FIG. 11 shows the configuration of a subarm and a drive part in accordance with one embodiment of the present invention;

FIG. 12 shows an example of how a tool for minimally invasive surgery is positioned in the surgery actuator in accordance with one embodiment of the present invention;

FIG. 13 is a bottom perspective view of a handling part for driving the tool for minimally invasive surgery in accordance with one embodiment of the present invention;

FIG. 14 is a cross-sectional view showing how a drive part and a handling part are connected in accordance with one embodiment of the present invention;

FIG. 15 is a perspective view showing an example of a tool for minimally invasive surgery used for the present invention;

FIGS. 16 and 17 are perspective views showing the configuration of a handling part in accordance with a first embodiment of the present invention;

FIG. 18 is a perspective view showing another example of the tool for minimally invasive surgery used for the present invention;

FIGS. 19 through 21 are perspective views showing the configuration of a handling part in accordance with a second embodiment of the present invention, with the views seen from different directions from each other;

FIG. 22 is a perspective view showing still another example of the tool for minimally invasive surgery used for the present invention;

FIGS. 23 through 25 are perspective views showing the configuration of a handling part in accordance with a third embodiment of the present invention, with the views seen from different directions from each other;

FIG. 26 is a perspective view showing still another example of the tool for minimally invasive surgery used for the present invention;

FIGS. 27 through 29 are perspective views showing the configuration of a handling part in accordance with a fourth embodiment of the present invention, with the views seen from different directions from each other;

FIG. 30 is a perspective view showing still another example of the tool for minimally invasive surgery used for the present invention;

FIGS. 31 through 33 are perspective views showing the configuration of a handling part in accordance with a fifth embodiment of the present invention, with the views seen from different directions from each other;

FIG. 34 is a perspective view showing still another example of the tool for minimally invasive surgery used for the present invention;

FIG. 35 is a perspective view showing still another example of the tool for minimally invasive surgery used for the present invention;

FIG. 36 is a perspective view showing the configuration of a main control part used for controlling the handling part of the tool for minimally invasive surgery used in embodiments in accordance with the present invention;

FIG. 37 shows actuation directions of first and second joysticks of the main control part in accordance with the present invention;

FIG. 38 shows actuation directions of an endoscope which is driven by the first joystick of the main control part in accordance with the present invention;

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FIG. 39 shows actuation directions of the surgery actuator by a robot arm which is driven by the second joystick of the main control part in accordance with the present invention;

FIG. 40 shows actuation directions of an adjusting lever of the main control part in accordance with the present invention;

FIG. 41 shows actuation directions of a tool for minimally invasive surgery in accordance with a fifth embodiment of the present invention; and

FIGS. 42 and 43 show actuation directions of a tool for minimally invasive surgery in response to pedal handling under the control of the main control part in accordance with the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

In the following detailed description, reference is made to the accompanying drawings that show, by way of illustration, specific embodiments in which the invention may be practiced. These embodiments are described in sufficient detail to enable those skilled in the art to practice the invention. It is to be understood that the various embodiments of the invention, although different, are not necessarily mutually exclusive. For example, a particular feature, structure, or characteristic described herein in connection with one embodiment may be implemented within other embodiments without departing from the spirit and scope of the present invention. Also, it is to be understood that the positions or arrangements of individual elements in the embodiment may be changed without separating the spirit and scope of the present invention. The following detailed description is, therefore, not to be taken in a limiting sense, and the scope of the present invention is defined only by the appended claims that should be appropriately interpreted along with the full range of equivalents to which the claims are entitled. In the drawings, like reference numerals identify like or similar elements or functions through the several views.

Hereinafter, preferred embodiments of the present invention will be explained in detail with reference to the accompanying drawing so that those skilled in the art can easily practice the invention.

Configuration of Surgical Robot System

FIG. 1 shows an overall configuration of a surgical robot system in accordance with one embodiment of the present invention, in which the surgical robot system includes an actuation robot 10 and a surgery actuator 40 both being associated with performing surgery on a patient on an operating table 1, and a main control part 300 for controlling the actuation robot 10 and the surgery actuator 40 in response to user manipulation. Handling of adjusting levers, joysticks and pedals by the main control part 300 is transformed to an electric signal and transmitted to the actuation robot 10 and/or the surgery actuator 40, and a device like an electric motor/hydraulic cylinder drives and controls the actuation robot 10 and/or the surgery actuator 40 based on a transmitted signal.

More details on prior art techniques of the configuration of the main control part 300 can be found in U.S. Pat. No. 4,853,874 entitled "Master-slave Manipulators with Scaling"; U.S. Pat. No. 5,779,623 entitled "Positioner for Medical Instruments"; and U.S. Pat. No. 6,102,850 entitled "Medical Robotic System". It should be noted, however, that the mention of such prior art techniques does not intend to limit the configuration of the main control part 300 of the present invention solely to the application of them.

FIG. 2 is a perspective view showing an overall configuration of the actuation robot 10 included in the surgical robot

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system in accordance with one embodiment of the present invention, in which the actuation robot **10** is composed of a base **20** (which may include a horizontal support **22**, a vertical support **24**, a vertical arm **26** and a horizontal arm **28**) for supporting all, and a robot arm **30** (which may include first through fourth robot arms **32**, **34**, **36** and **38**) connected to the base **20** and making surgical motions in response to user manipulation.

The base **20** is preferably configured to prevent the entire actuation robot **10** against vibrations caused by external forces so as to make surgery proceed as smooth as possible. To this end, the base **20** includes a horizontal support **22** and a vertical support **24** made of high load-bearing materials, and thus can stand firm on the ground.

Moreover, the base **20** includes a vertical arm **26** operating in a surge direction (i.e., forward and backward motions in an axis direction and in a roll direction, and a horizontal arm **28** operating in a pitch direction. The vertical arm **26** and the horizontal arm **28** can control positions of robot arms (to be described later).

The robot arm **30** is connected to the surgery actuator **40**, with the surgery actuator **40** having an endoscope and/or tools for minimally invasive surgery. The robot arm **30** can be configured to operate in a surge direction, a pitch direction and/or in a roll direction, in response to user manipulation. More details on this will be provided below.

FIGS. **3** and **4** show the configuration and operations of robot arms in accordance with one embodiment of the present invention. As illustrated in FIGS. **3** and **4**, the robot arm **30** connected to the base **20** is constituted by first through fourth robot arms **32**, **34**, **36** and **38**.

The first robot arm **32** operates in a roll direction with respect to the horizontal arm **28** (this can cause the surgery actuator **40** to operate in a yaw direction), as shown. The second robot arm **34** operates in a pitch direction with respect to the first robot arm **32** (this can cause the surgery actuator **40** to operate in a pitch direction). Here, as illustrated in FIG. **4**, the third robot arm **34** preferably operates in parallel to the vertical axis of the first robot arm **32**, such that an operational direction of the fourth robot arm **38** in the pitch direction is substantially identical to an operational direction of the second robot arm **34** in the pitch direction. Referring to FIG. **4**, the surgery actuator **40** operates in the pitch direction with respect to an intersection (i.e., 'A' portion) between the vertical axis of the first robot arm **32** and the vertical axis of the surgery actuator **40**. FIG. **5** shows that the surgery actuator **40** in accordance with one embodiment of the present invention operates in the surge direction in parallel to the vertical axis of the fourth robot arm **38**. Once the surgery actuator **40** is properly positioned by the first through fourth robot arms **32**, **34**, **36** and **38**, it can operate in the surge and roll directions independently.

FIGS. **6** and **7** show a detailed configuration of the surgery actuator **40** in accordance with one embodiment of the present invention. As illustrated in FIGS. **6** and **7**, an endoscope **50** and tools **100** for minimally invasive surgery are formed in a bundle within a cylindrical body **42** having a preset length for the surgery actuator **40**. The endoscope **50** and the tool **100** for minimally invasive surgery are driven by a drive unit (not shown) that is disposed at the surgical actuator **40**, in response to user manipulation, so as to operate individually in a surge direction and in a roll direction.

Turning now to FIGS. **8** and **9**, there are shown examples where the endoscopes **50** and **50A** and the tool **100** for minimally invasive surgery are formed in a bundle in accordance with one embodiment of the present invention. Preferably, the endoscopes **50** and **50A** and the tool **100** for minimally inva-

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sive surgery are positioned within the surgery actuator **40** in form of a bundle (more preferably, the endoscopes **50** and **50A** and the tool **100** for minimally invasive surgery may be inserted into a patient's body in form of a bundle). To this end, a surgical port **90** as shown in FIG. **8** may be utilized. More information on the surgical port **90** can be found in the detailed description of specification for Korean Patent Application No. 2008-99872 filed by the same applicant, the contents of which are incorporated herein by reference in its entirety. The endoscopes **50** and **50A** may have a linear form as illustrated in FIG. **8**, or endoscopes with diverse ranges of bending such as joints or freely bending flexible endoscopes as illustrated in FIG. **9** and described in Korean Patent Application Nos. 2008-51248, 2008-61894, 2008-79126 and 2008-90560 may also be used.

Meanwhile, depending on the kind of surgery, it is sometimes better for a user to see an operation field of the patient at an oblique angle from above. Therefore, to enable the user (i.e., surgeon) to see the operation field of the patient nearly identically as seeing with the naked eye, the endoscope **50B** may be built at a preset oblique angle with respect to the tool **100** for minimally invasive surgery as illustrated in FIG. **10**. The oblique angle can be set depending on the user's needs.

Among the endoscopes positioned within the surgery actuator **40**, the endoscope **50A** having an articulation function may be connected with a drive roller (to be described later), but may not be connected as well.

Now, details on FIG. **11** will be given. FIG. **11** shows the configuration of a subarm **60** and a drive part **80** in accordance with one embodiment of the present invention. As illustrated in FIG. **11**, the tool **100** for minimally invasive surgery is connected to one end (the end on the side of the drive part **80**) of the subarm **60** in form of a linear tube. A mount **70** is positioned at one end of the subarm **60**, with the mount **70** including a groove **72**, a linear groove **74**, and a cover **76**. Additionally, the drive part **80**, which includes plural drive rollers **82** for driving a handling part (to be described later) used for the control of the operation of the tool **100** for minimally invasive surgery, can be connected. The drive rollers **82** may be driven by drive units well-known in the prior art.

FIG. **12** shows an example of how the tool **100** for minimally invasive surgery is positioned within the surgery actuator **40** in accordance with one embodiment of the present invention, FIG. **13** is a bottom perspective view of the handling part **200** for driving of the tool **100** for minimally invasive surgery, and FIG. **14** is a cross-sectional view showing how the drive part **80** and the handling part **200** are connected. The following is a more detailed explanation about disposition of the tool **100** for minimally invasive surgery, with reference to FIG. **11** and FIGS. **12** through **14**.

As noted earlier, the drive part **80** preferably including the plural drive rollers **82** is positioned at the end of the subarm **60**. The handling part **200** for controlling the tool **100** for minimally invasive surgery may be placed contiguous with the drive part **80**. Moreover, the mount **70** includes a groove **72** and a linear groove **74**, and the handling part **200** includes a protrusion **102** and a linear protrusion **104** to join to each other. After the protrusion **102** and the linear protrusion **104** are fitted into the groove **72** and the linear groove **74**, respectively, the cover **76** is placed over them.

With the mount **70** and the handling part **200** being joined to each other as described above, it is sometimes necessary to transfer a rotational motion of the drive rollers **82** of the drive part **80** to the tool **100** for minimally invasive surgery via a drive pulley (to be described later) of the handling part **200**. To this end, as illustrated in FIG. **14**, a connection roller **256**

is positioned at one end of a drive shaft **206** (6th drive shaft **206** as will be described later) constituting the handling part **200** to be exposed outside of the handling part **200**, and then the connection roller **256** is brought into contact with one drive roller **82** of the drive part **80**. By doing so, the drive pulley **216** is operationally coupled in its rotation with the rotational motions of the drive roller **82** and the connection roller **256**. To make the power transfer proceed smoothly from the drive roller **82** to the connection roller **256**, a contact surface between the drive roller **82** and the connection roller **256** may have a groove and a projection. Although the joint between the drive roller **82** close to the 6th drive shaft **206** out of many drive shafts that constitute the handling part **200** and the connection roller **256** has been explained, such joint or link can equally be made around other drive shafts that constitute the handling part **200**.

For information, the tool **100** for minimally invasive surgery in accordance with one embodiment of the present invention described in the aforementioned Korean Patent Application No. 2008-90560 is illustrated in FIG. **12**, but other tools for minimally invasive surgery, namely, the surgical tools according to each embodiment in the other Korean Patent Applications mentioned above, may be positioned in diverse and creative manner. That is to say, the selection of a tool for minimally invasive surgery used for the surgery actuator **40** can be made voluntarily by the user.

Hereinafter, various embodiments of the present invention will be described, with a primary focus on the configuration of the handling part **200** that allows the tool **100** for minimally invasive surgery to be positioned and operate within the surgery actuator **40**.

Configurations of Tool for Minimally Invasive Surgery and Handling Part

Embodiment I

FIG. **15** is a perspective view showing an example of the tool **100** for minimally invasive surgery used for the present invention.

The tool **100** for minimally invasive surgery includes a shaft **110** (i.e., main shaft), first and second actuating shafts **120** and **130** connected to one end of the main shaft **110** through first and second yaw actuating parts **112** and **122**, respectively, and an end effector **140** connected to the end of the second actuating shaft **130** with a pitch actuating part **132**. Also, a handling part **200** is positioned at the other end of the shaft **110** to actuate the first and second actuating shafts **120** and **130**, and to actuate the end effector **140**.

More details on the configurations of the first and second actuating shafts **120** and **130** extendedly connected to one end of the shaft **110**, the end effector **140** and yaw cable **YC** connected thereto, and first and second pitch cables **PC1** and **PC2** can be found in the first embodiment of the detailed description for the invention disclosed in Korean Patent Application No. 2008-90560, so any details on those configurations will be omitted here.

The configuration of the handling part **200** will now be discussed in more detail.

FIGS. **16** and **17** are perspective views showing the configuration of the handling part **200** in accordance with a first embodiment of the present invention, with the views seen from different directions. As illustrated in the drawings, first through sixth drive shafts **201-206** and first through sixth actuating shafts **221-226** are sequentially positioned oppositely to each other in parallel, and the second through sixth actuating shafts and the second through sixth actuating shafts,

except for the first drive shaft and the first actuating shaft, are provided with second through sixth drive pulleys **212-216** and second through sixth actuating pulleys **232-236**, respectively, to have cables wound around them, thereby letting them rotate around the shafts (where the pulley for each of the first shafts will be explained in another embodiment). Moreover, each of the drive shafts is connected to the corresponding drive roller **82** to receive a rotational motion therefrom. Meanwhile, the pulleys of the drive shafts or the actuating shafts are preferably positioned in different heights from each other to prevent interferences between the cables wound around the pulleys.

The drive pulleys and the actuating pulleys positioned oppositely from each other may have the same diameter to have the same drive range and the same actuating range, but they may also be given different diameters to have different drive ranges and different actuating ranges from each other. Besides, the drive pulleys and the actuating pulleys may have a proper width, taking the width of cables wound around each of them into consideration.

The following is a further explanation about an example of how yaw cable **YC** and the first and second pitch cables **PC1** and **PC2** are connected to the drive pulleys and the actuating pulleys of the handling part **200**.

The second actuating pulley **232** is connected to the first yaw actuating part **112** by the yaw cable **YC**, so that the first actuating shaft **120** is controlled to operate in a yaw direction according to the rotation of the second actuating pulley **232**. Since the second actuating pulley **232** is also connected to the second drive pulley **212** by another cable, it can receive a rotational motion from the second drive pulley **212**.

The third actuating pulley **233** is connected to the first yaw actuating part **112**, to the second yaw actuating part **122**, and to the pitch actuating part **132** by the second pitch cable **PC2**. Since the third actuating pulley **233** is also connected to the third drive pulley **213** by the second pitch cable **PC2**, it can receive a rotational motion from the third drive pulley **213**. One end of the second pitch cable **PC2** can be secured to the third drive pulley **213**. The other end of the second pitch cable **PC2** can be connected to the fifth drive pulley **215** through the fifth actuating pulley **235**.

Meanwhile, the fourth actuating pulley **234** is connected to the first yaw actuating part **112**, to the second yaw actuating part **122** and to the pitch actuating part **132** by the first pitch cable **PC1**. Since the fourth actuating pulley **234** is also connected to the fourth drive pulley **214** by means of the first pitch cable **PC1**, it can receive a rotational motion from the fourth drive pulley **214**. One end of the first pitch cables **PC1** can be secured to the fourth drive pulley **214**. The other end of the first pitch cable **PC1** can be connected to the sixth drive pulley **216** via the sixth actuating pulley **236**.

The following is a detailed explanation about the operations of the first and second actuating shafts **120** and **130** and the end effector **140** by the handling part **200** having the cable connections described above.

First, a yaw-wise rightward rotation mechanism of the first actuating shaft **120** with respect to the main shaft **110** will now be explained below.

When the second drive pulley **212** rotates clockwise, its rotational motion is transmitted to a yaw cable pulley (not shown) of the first yaw actuating part **112**, and when the yaw cable pulley rotates accordingly, the first actuating shaft **120** rotates yaw-wise rightward.

At this time, the third and fifth drive pulleys **213** and **215** make the second pitch cable **PC2** rotate in an unwind direction from the handling part **200**, and the fourth and sixth drive pulleys **214** and **216** make the first pitch cable **PC1** rotate in a

pull direction towards the handling part **200**. Thus, the second actuating shaft **130** may remain in a consistent position with respect to the first actuating shaft **120**.

Now, a yaw-wise leftward rotation mechanism of the second actuating shaft **130** with respect to the first actuating shaft **120** will be explained below.

First, a yaw cable pulley (not shown) of the first yaw actuating part **112** is not allowed to rotate by securing the second drive pulley **212**. By doing so, the first actuating shaft **120** is not allowed to rotate, either. In this state, the third and fifth drive pulleys **213** and **215** rotate the second pitch cable **PC2** in the pull direction towards the handling part **200**, and the fourth and sixth drive pulleys **214** and **216** rotate the first pitch cable **PC1** in the unwind direction from the handling part **200**. Accordingly, the second actuating shaft **130** rotates yaw-wise leftward with respect to the first actuating shaft **120**.

A downward pitch-wise rotation mechanism of the end effector **140** will now be explained below.

First, a yaw cable pulley (not shown) of the first yaw actuating part **112** is not allowed to rotate by securing the second drive pulley **212**. By doing so, the first actuating shaft **120** is not allowed to rotate, either. In this state, the third and fourth drive pulleys **213** and **214** connected to the second and first pitch cables **PC2** and **PC1** rotate the second and first pitch cables **PC2** and **PC1** in the pull direction towards the handling part **200**, and the fifth and sixth drive pulleys **215** and **216** rotate the second and first pitch cables **PC2** and **PC1** in the unwind direction from the handling part **200**. By doing so, while the second actuating shaft **130** is immobilized, the end effector **140** connected to the first and second pitch cables **PC1** and **PC2** rotate in a way that its two rods face downward pitch-wise at the same time.

The description so far has been focused mainly on the operational example of the tool **100** for minimally invasive surgery illustrated in FIG. **15**, but it is obvious to a person having ordinary skill in the art that the same principle mechanism explained above may also be realized in different operational examples from the operational example provided here.

Embodiment II

FIG. **18** is a perspective view showing another example of a tool **100A** for minimally invasive surgery used for the present invention.

The configuration of the tool **100A** for minimally invasive surgery is basically similar to that of the tool **100** for minimally invasive surgery in accordance with the first embodiment, but an end effector **140A** thereof is configured differently from the end effector **140** of the first embodiment. In addition, the tool **100A** for minimally invasive surgery includes pitch cables **PC**, first and second yaw cables **YC1** and **YC2**, and an opening/closing cable **OC**. Since more information on the configuration of this embodiment can be found in the first embodiment of the detailed description for the invention disclosed in Korean Patent Application No. 2008-79126, more details thereon will be omitted here.

The following is a detailed explanation about the configuration of a handling part **200A**.

FIGS. **19** through **21** are perspective views showing the configuration of the handling part **200A** in accordance with the second embodiment of the present invention, with the views seen from different directions from each other. As illustrated in the drawings, first through sixth drive shafts **201A-206A** are positioned in parallel to first through third actuating shafts **221A-223A**. Moreover, the first through third actuating shafts **221A-223A** may be sequentially positioned

opposedly from the third through fifth drive shafts **203A-205A**. The drive shafts and the actuating shafts positioned opposedly from each other are provided with the third through fifth drive pulleys **213A-215A** and the first through third actuating pulleys **231A-233A**, respectively, thereby allowing the pulleys to rotate about the corresponding shafts. As noted in the previous embodiment, the drive rollers **82** can be connected to the drive shafts. This can be also equally applied to the embodiments to be described later.

Moreover, similar to the previous embodiment, the pulleys for the drive shafts or the actuating shafts may be positioned at different heights to prevent interferences between the cables wound around the pulleys.

Meanwhile, the drive pulleys and the actuating pulley may be given the same diameter or width, as those in the previously explained embodiment.

However, according to this embodiment, the first through third actuating pulleys **231A-233A** each may be constituted with a pair of pulleys. The lower pulley in the actuating pulley pair is a pulley for receiving a drive force from the drive shaft, and the upper pulley in the actuating pulley pair is a pulley for transferring the received drive force to the opposite side of the shaft **110A**.

The following is a description about an example of how the opening/closing cable **OC**, the pitch cables **PC**, and the first and second yaw cables **YC1** and **YC2** are connected to the drive pulleys and the actuating pulleys in the handling part **200A**.

As shown in the drawings, one end of the opening/closing cable **OC** is wound around the second drive pulley **212A** and secured thereto. The other end of the opening/closing cable **OC** is connected to the end effector **140A**, so if the opening/closing cable **OC** is pulled according to the rotation of the second drive pulley **212A**, the end effector **140A** is closed; if the opening/closing cable **OC** is released, the end effector **140A** is open by the restoring force of its spring.

Meanwhile, the first actuating pulley **231A** is connected to a pitch actuating part **132A** by the pitch cables **PC**. The first actuating pulley **231A** is also connected to a third drive pulley **213A** by another cable, so it can receive a rotational motion from the third drive pulley **213A**.

The upper pulley of the second actuating pulley pair **232A** and the upper pulley of the third actuating pulley pair **233A** are connected to the first yaw cable **YC1** and to the second yaw cable **YC2**, respectively. The second and third actuating pulleys **232A** and **233A** can also be driven by fourth and fifth drive pulleys **214A** and **215B**.

The following is a detailed explanation about the operations of the first and second actuating shafts **120A** and **130A** and the end effector **140A** by the handling part **200A** having the cable connections described above.

First, a yaw-wise rightward rotation mechanism of the first actuating shaft **120A** with respect to the main shaft **110A** will be explained below.

With the second drive pulley **212A** and the third drive pulley **213A** wound around with the opening/closing cable **OC** and with the pitch cables **PC**, respectively, being immovably secured not to rotate in any direction, if the fourth drive pulley **214A** and the fifth drive pulley **215A** rotate clockwise, the first actuating pulley **231A** and the second actuating pulley **232A** wound around with the first and second yaw cables **YC1** and **YC2**, respectively, pull the first and second yaw cables **YC1** and **YC2** on the right side towards the handling part **200A**, and unwind the first and second yaw cables **YC1** and **YC2** on the left side from the handling part **200A**, such that the first actuating shaft **120A** rotates yaw-wise rightward.

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Now, a yaw-wise leftward rotation mechanism of the second actuating shaft **130A** with respect to the first actuating shaft **120A** will be explained below.

With the second drive pulley **212A**, the third drive pulley **213A** and the fourth drive pulley **214A** being immovably secured not to rotate in any direction, if the fifth drive pulley **215A** rotates counterclockwise, the third actuating pulley **23A** also rotates counterclockwise. As such, the second yaw cable **YC2** on the left side of the third actuating pulley **233A** is pulled towards the handling part **200A**, and the second yaw cable **YC2** on the right side is unwound from the handling part **200A**. Accordingly, the second actuating shaft **130A** rotates yaw-wise leftward with respect to the first actuating shaft **120A**.

A downward pitch-wise rotation mechanism of the end effector **140A** will now be explained below.

With the second drive pulley **212A**, the fourth drive pulley **214A** and the fifth drive pulley **215A** being immovably secured not to rotate in any direction, if the third drive pulley **213A** wound around with the pitch cable **PC** rotates clockwise, the lower pitch cable **PC** is pulled, while the upper pitch cable **PC** is unwound, such that the end effector **140A** rotates downward pitch-wise.

The description so far has been focused mainly on the operational example of the tool **100A** for minimally invasive surgery illustrated in FIG. **18**, but it is obvious to a person having ordinary skill in the art that the same principle mechanism explained above can also be realized in different operational examples from the operational example provided here.

Embodiment III

FIG. **22** is a perspective view showing another example of a tool **100B** for minimally invasive surgery used for the present invention.

The configuration of the tool **100B** for minimally invasive surgery is basically similar to that of the tools **100** and **100A** for minimally invasive surgery in accordance with the previously explained embodiments, but it has a characteristic configuration for a connection part **132B** connecting an end effector **140B** to a second actuating shaft **130B**. In addition, the tool **100B** for minimally invasive surgery includes first and second pitch cables **PC1** and **PC2**, and first and second yaw cables **YC1** and **YC2**. Since more information on the configuration of this embodiment can be found in the fifth embodiment of the detailed description for the invention disclosed in Korean Patent Application No. 2008-90560, more details thereon will be omitted here.

The following is a description about the configuration of a handling part **200B**.

FIGS. **23** through **25** are perspective views showing the configuration of the handling part **200B** in accordance with the third embodiment of the present invention, with the views seen from different directions from each other. As illustrated in the drawings, first through sixth drive shafts **201B-206B** are sequentially positioned in parallel to first through sixth actuating shafts **221B-226B**. As illustrated in the drawings, these shafts have drive pulleys and actuating pulleys having the similar functions and similar configuration features to those of the previously explained embodiments.

The following is an explanation about an example of how the first and second pitch cables **PC1** and **PC2** and the first and second yaw cables **YC1** and **YC2** are wound around the corresponding drive pulleys and actuating pulleys.

First, the second yaw cable **YC2** being immovably secured to the first drive pulley **211B**, winds around the first drive pulley **211B** about twice in a loop form, and then the other end

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of each is immovably secured to the second yaw actuating part **122B** via the first actuating pulley **231B**. As the second yaw cable **YC2** winds around the first drive pulley **211B** twice, it causes no interference with the first yaw cable **YC1**. By the medium of the second cable **YC2**, the first actuating pulley **231B** can control a yaw-wise operation of the second actuating shaft **130B**.

Next, the first yaw cable **YC1** connects the second actuating pulley **232B** and the first yaw actuating pulley **112B** to let the first actuating shaft **120** rotate in a yaw direction according to the rotation of the second actuating pulley **232B**. At this time, the second actuating pulley **232B** can also be driven by the second drive pulley **212B** by the medium of another cable.

Meanwhile, the first and second pitch cables **PC1** and **PC2** have the same connections as those of the first and second pitch cables **PC1** and **PC2** in the first embodiment that was explained earlier with reference to FIGS. **16** and **17**. The first and second pitch cables **PC1** and **PC2** can control the operations of the end effector **140B** in the pitch and yaw directions by controlling the pitch-wise actuating joint and the yaw-wise actuating joint as explained in the fifth embodiment of the detailed description for the invention disclosed in Korean Patent Application No. 2008-90560.

The following is a detailed explanation about the operations of the first and second actuating shafts **120B** and **130B** and the end effector **140B** by the handling part **200B** having the cable connections described above.

First, a yaw-wise rightward rotation mechanism of the first actuating shaft **120B** with respect to the main shaft **110B** will now be explained below.

When the first and second drive pulleys **211B** and **212B** rotate clockwise, their rotational motions are transmitted to a yaw cable pulley (not shown) and a connection pulley (not shown) of the first yaw actuating part **112B**, respectively, through the second and first yaw cables **YC2** and **YC1** wound around the first and second actuating pulleys **231B** and **232B**, so the first actuating shaft **120B** rotates yaw-wise rightward. In this case, even though connection pulleys (not shown) positioned on both ends of a yaw cable pulley (not shown) of the first yaw actuating part **112B** may rotate independently of the yaw cable pulley (not shown), in order to protect other elements from the influences of the operation of the first actuating shaft **120B**, the third and fifth drive pulleys **213B** and **215B** rotate in the unwind direction of the second pitch cable **PC2**, while the fourth and sixth drive pulleys **214B** and **216B** rotate in the pull direction of the first pitch cable **PC1**.

Now, a yaw-wise leftward rotation mechanism of the second actuating shaft **130B** with respect to the first actuating shaft **120B** will be explained below.

First, a yaw cable pulley (not shown) is not allowed to rotate by securing the second drive pulley **212B**. By doing so, the first actuating shaft **120B** is not allowed to rotate, either.

In this state, if the first drive pulley **211B** wound around the second yaw cable **YC2** rotates counterclockwise, the second actuating shaft **130B** where one end of the second yaw cable **YC2** is wound around and secured to is pulled towards the handling part **200B**.

Also, the third and fifth drive pulleys **213B** and **215B** wound around with the second pitch cable **PC2** rotate to let the second pitch cable **PC2** pulled towards the handling part **200B**, and the fourth and sixth drive pulleys **214B** and **216B** rotate to let the first pitch cable **PC1** rotate in the unwind direction from the handling part **200B**. By doing so, the second actuating shaft **130B** rotates yaw-wise leftward with respect to the first actuating shaft **120B**.

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A yaw-wise leftward rotation mechanism of the end effector **140B** with respect to the connection part **132B** will now be explained below.

First, the second and first yaw cables **YC2** and **YC1** are not allowed to operate by securing the first and second drive pulleys **211B** and **211B(212B)**; 곁토요망).

In this state, the third and fifth drive pulleys **213B** and **215B** let the second pitch cable **PC2** rotate in the pull direction towards the handling part **200B**, and the fourth and sixth drive pulleys **214B** and **216B** let the first pitch cable **PC1** rotate in the unwind direction from the handling part **200B**.

Because the first and second actuating shafts **120B** and **130B** cannot rotate with the first and second yaw cables **YC1** and **YC2** being immovably secured, the end effector **140B** can rotate yaw-wise leftward with respect to the connection part **132B** by the operations of the first and second pitch cables **PC1** and **PC2**.

Now, a downward pitch-wise rotation mechanism of the end effector **140B** will be explained below.

First, the first actuating shaft **120B** and the second actuating shaft **130B** are not allowed to rotate by securing the first and second drive pulleys **211B** and **212B**.

The third and fourth drive pulleys **213B** and **214B** wound around with the second and first pitch cables **PC2** and **PC1** let the second and first pitch cables **PC2** and **PC1** rotate in the pull direction towards the handling part **200B**, and the fifth and sixth drive pulleys **215B** and **216B** let the second and first pitch cables **PC2** and **PC1** rotate in the unwind direction from the handling part **200B**. As such, the first and second actuating shafts **120B** and **130B** are in immovable state, and the end effector **140B** connected with the first and second pitch cables **PC1** and **PC2** rotates downward pitch-wise, with its two rods facing downward at the same time.

The description so far has been focused mainly on the operational example of the tool **100B** for minimally invasive surgery illustrated in FIG. **22**, but it is obvious to a person having ordinary skill in the art that the same principle mechanism explained above can also be realized in different operational examples from the operational example provided here.

Embodiment IV

FIG. **26** is a perspective view showing still another example of a tool **100C** for minimally invasive surgery used for the present invention.

The configuration of the tool **100C** for minimally invasive surgery is basically similar to that of the tools **100**, **100A** and **100B** for minimally invasive surgery in accordance with the previously explained embodiments, but it has a characteristic configuration for the third yaw actuating part **132C** connecting an end effector **140C** together with the pitch actuating part **134c** to the second actuating shaft **130C**. In addition, the tool **100C** for minimally invasive surgery includes a pitch cable **PC**, first through third yaw cables **YC1**, **YC2** and **YC3**, and an opening/closing cable **OC**. Since more information on the configuration of this embodiment can be found in the fourth embodiment of the detailed description for the invention disclosed in Korean Patent Application No. 2008-79126, more details thereon will be omitted here.

The following is a detailed explanation about the configuration of a handling part **200C**.

FIGS. **27** through **29** are perspective views showing the configuration of the handling part **200C** in accordance with the fourth embodiment of the present invention, with the views seen from different directions from each other. As illustrated in the drawings, the positions and configurations of the first through sixth drive shafts **201C-206C** and their cor-

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responding first through third actuating shafts **221C-223C**, and the positions and configurations of the third through fifth drive shafts **213C-215C** and their corresponding first through third actuating pulleys **231C-233C** are similar to those in the second embodiment explained previously.

Meanwhile, this embodiment differs from the second embodiment in that the fourth actuating shaft **224C** is positioned opposedly from the sixth actuating shaft **206C**, and the fourth actuating pulley **234C** is positioned at the fourth actuating shaft **224C**, thereby being driven together by the sixth drive pulley **216C**.

The fourth actuating pulley **234C** set forth above drives the third yaw actuating part **132C** through the third yaw cable **YC3** to let the operation of the end effector **140C** controlled more in the yaw direction.

Embodiment V

FIG. **30** is a perspective view showing still another example of a tool **100D** for minimally invasive surgery used for the present invention.

The configuration of the tool **100D** for minimally invasive surgery is basically similar to that of the tools **100**, **100A**, **100B** and **100C** for minimally invasive surgery in accordance with the previously explained embodiments, but it has a characteristic configuration for how the first and second yaw cables **YC1** and **YC2** are wound around their corresponding actuation pulleys **233D** and **232D**. Since more information on the configuration of this embodiment can be found in the fifth embodiment of the detailed description for the invention disclosed in Korean Patent Application No. 2008-79126, more details will be omitted here.

To see an example of how the first and second yaw cables **YC1** and **YC2** are wound around in the handling part **200D** with reference to FIGS. **31** through **33** (especially, FIG. **33**), the third actuating pulley **233D** and the second actuating pulley **232D** where the first and second yaw cables **YC1** and **YC2** are wound around, respectively, are double in-line pulleys or dual pulleys, so the first and second yaw cables **YC1** and **YC2** are wound around both sides about the third yaw cable **YC3**.

Embodiment VI

FIG. **34** is a perspective view showing still another example of a tool **100E** for minimally invasive surgery used for the present invention. The configuration of this embodiment is identical to that of the third embodiment, except that a non-openable hook electrode has been utilized for the end effector **140E**. In fact, the end effector **140E** may take a variety of forms depending on the user's needs as long as it would not open or close.

FIG. **35** is a perspective view showing still another example of a tool **100F** for minimally invasive surgery used for the present invention. The configuration of this embodiment is identical to that of the fifth embodiment, except that an opening/closing cable is eliminated because a non-openable hook electrode has been utilized for the end effector **140F**.

Configuration of Main Control Part

FIG. **36** is a perspective view showing the configuration of a main control part **300** used for controlling the handling part **200** of the tool **100** for minimally invasive surgery used in embodiments in accordance with the present invention. As shown in the drawing, the main control part **300** includes a table **310** having a predetermined height, a monitor **320** for displaying an image captured by an endoscope **50**, a first joystick **330a** for controlling the operation of the endoscope,

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a second joystick **330b** for controlling the position of the surgery actuator **40** by controlling the operation of the robot arm **30**, a pair of adjusting levers **340** for controlling the operation of the tool **100** for minimally invasive surgery, and a pair of pedals **350** for regulating predetermined operations of the tool **100** for minimally invasive surgery. This configuration is provided for illustrative purpose only, and the main control part **300** may take a variety of modified configurations, as long as it allows the user to operate the robot arm **30**, the surgery actuator **40**, the endoscope **50** positioned at the surgery actuator **40** and the tool **100** for minimally invasive surgery according to the user's intention.

Hereinafter, the operation control by the first joystick **330a**, the second joystick **330b** and the adjusting levers **340** will be explained with reference to drawings.

FIG. **37** shows actuation directions of the first and second joysticks **330a** and **330b**, FIG. **38** shows actuation directions of the endoscope **50** which is driven by the first joystick **330a**, and FIG. **39** shows actuation directions of the surgery actuator **40** by the robot arm **30** which is driven by the second joystick **330b**.

First, the configurations of the first and second joysticks **330a** and **330b** will be explained below.

As shown in the drawings, the first and second joysticks **330a** and **330b** are in form of dial type knobs **334a** and **334b** that are attached to the end of sticks **332a** and **332b** having a predetermined length, such that the first joystick **330a** is allowed to handle the stick **332a** in a surge direction and in a roll direction using the knob **334a** and the second joystick **330b** is allowed to handle the stick **332b** in a surge direction, in a pitch direction, in a yaw direction and a roll direction using the knob **334b**.

The following is an explanation about how the surgery actuator **40** and the endoscope **50** operate by the joysticks.

As illustrated in FIG. **37**, the user can handle the second joystick **330b** in a surge direction, in a pitch direction, in a yaw direction and/or in a roll direction, as he or she intended. That is to say, the user handles the second joystick **330b** to drive the first through fourth robot arms **32**, **34**, **36** and **38** that constitute the robot arm **30**, so as to control the surgery actuator **40** in a surge direction, in a pitch direction, in a yaw direction and/or in a roll direction, as illustrated in FIG. **39**.

Also, the user can handle the first joystick **330a** in a surge direction and in a roll direction. By handling the first joystick **330a**, as illustrated in FIG. **38**, the user can control the endoscope **50** in the surgery actuator **40** so that it operates in a surge direction and in a roll direction. However, it should be noted that if the first joystick **330a** which is controllable only in the surge and roll directions is used, only a rigid endoscope having no articulation function can be used. Thus, in case of using an endoscope having an articulation function, it is preferable to handle the first joystick **330a**, similar to the second joystick **330b**, in a surge direction, in a pitch direction, in a yaw direction and/or in a roll direction.

Hereinafter, the operation control over the tool **100** for minimally invasive surgery by the adjusting lever **340** will be described with reference to drawings.

Because the adjusting lever **340** is for controlling the operation of the tool **100** for minimally invasive surgery, it will be helpful to use as many adjusting levers **340** as the tools **100** for minimally invasive surgery. That is, as illustrated in FIG. **36**, a pair of (two) adjusting levers **340** can be utilized. However, if there are too many adjusting handles, the user is likely to feel confused during surgery. In such case, the user may use the pedals **350** to select a desired tool **100** for minimally invasive surgery controlled by the adjusting lever **340**.

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Referring now to FIG. **40**, the adjusting lever **340** includes first, second and third handling rods **344a**, **344b** and **344c** connected in sequence by first and second yaw rotational axes **346a** and **346b**. The first rod **342a** and the second rod **342b**, each having hole(s), are connected by a predetermined rotation axis, and they are again connected to one end of the third handling rod **344c** by a pitch rotation axis **346c**.

As the user handles the adjusting lever **340**, the first and second rods **342a** and **342b** move in the pitch direction along the pitch rotation axis **346c**, the first handling rod **344a** operates in the surge direction and in the roll direction, and the second and third handling rods **344b** and **344c** operate in the yaw direction along the first and second yaw rotation axes **346a** and **346b**.

Meanwhile, if the tool **100** for minimally invasive surgery is openable/closeable, the user may open or close the end effector **140** by holding the first rod **342a** and the second rod **342b** and then increasing or decreasing an angular distance between them.

FIG. **41** shows an actuation direction of the tool **100D** for minimally invasive surgery in accordance with the fifth embodiment of the present invention explained above. To explain the operation control by the adjusting lever **340** for example, when the first handling rod **344a** of the adjusting lever **340** moves in the surge direction or in the roll direction, the shaft **110D** operates corresponding to it. Also, the end effector **140D** may operate in the pitch direction, or may be open/closed by handling the first rod **342a** and the second rod **342b**. Moreover, the first and second actuating shafts **120D** and **130D** may operate in the yaw directions yaw1 and yaw2 by handling the second and third handling rods **344b** and **344c**. In addition, if the adjusting lever **340** is configured to enable the first and second rods **342a** and **342b** to operate even in the yaw direction with respect to the third handling rod **344c**, the rods may also operate in the yaw direction yaw3 of the end effector **140D** illustrated in FIG. **41**.

Whether to operate the rods, by handling the adjusting lever **340**, in the yaw direction yaw1 or yaw2 of the first or second actuating shaft **120D** or **130D** or in the yaw direction yaw3 of the end effector **140D** can be achieved by operating the pedals **350** (to be described later).

So far, the configuration and operation of the adjusting lever **340** have been discussed assuming that the lever is adapted to the first embodiment or the fifth embodiment of the tool for minimally invasive surgery of the present invention. However, it will be obvious to a person having ordinary skill in the art that modifications may be made to the adjusting lever **340** according to a corresponding tool for minimally invasive surgery without departing from the scope or principle applied to other embodiments of the present invention.

Lastly, the functions of the pedals **350** will be explained. As discussed earlier, the adjusting lever **340** includes three handling rods connected in sequence by two yaw-wise rotation joints, so the user should know, before making any choice, which yaw actuating part the yaw-wise rotation joints of his or her adjusting lever **340** belong to. That is, in case there are more than three yaw actuating parts or similar elements as in the third embodiment through the sixth embodiment, it would be better if the user knows which yaw actuating part or similar element the yaw-wise rotation joint of the adjusting lever **340** corresponds to and then takes suitable countermeasures in timely manner.

The above will be explained further with an illustration of FIGS. **42** and **43**. Although the tool for minimally invasive surgery shown therein has a similar configuration to that of

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the tool **100B** for minimally invasive surgery in accordance with the third embodiment, the present invention is not necessarily limited thereto.

First, the user steps on the pedals **350** to select a yaw actuating part corresponding to the rotation joint of the first or the second yaw rotation axis **346a**, **346b**. For instance, as illustrated in FIGS. **42** and **43**, in the initial state (where the pedals **350** are not pressed, which corresponds to the left side view in FIGS. **42** and **43**), rotation joints of the first and second yaw rotation axes **346a** and **346b** of the adjusting lever **340** correspond to the first and second yaw actuating parts **112B** and **122B**, respectively. On the other hand, with the user stepping on the pedals **350**, rotation joints of the first and second yaw rotation axes **346a** and **346b** may correspond to the second yaw actuating part **122b** and the connection part **132B**, respectively (which corresponds to the right side view in FIGS. **42** and **43**).

Needless to say, a person having ordinary skill in the art may use the pedals **350** differently from that explained in this embodiment. For example, if there are more yaw actuating parts, it may be possible to have a yaw actuating part corresponding to the rotation joint of the yaw rotation axis of the adjusting lever **340** be determined depending on the frequency for stepping on the pedals **350**, or to simply operate the pedals **350** to determine which yaw actuating part the user needs to control without having to provide the adjusting lever **340** with more than two yaw rotation axes to do so.

Moreover, if there are more than three tools **100** for minimally invasive surgery positioned within the surgery actuator **40**, it may also be possible for the user to select which tool **100** for minimally invasive surgery the adjusting levers **340** on both sides correspond to, based on the frequency for stepping on the pedals **350**.

As described above, the present invention provides a surgical robot system suitable for use with a tool for carrying out a minimally invasive surgery in a dexterous and convenient manner.

In addition, the present invention presents a surgical robot system for enabling a user to perform remote surgery even if a patient to be operated on is far away in a physically different location.

Furthermore, the present invention suggests a surgical robot system for helping a user perform a minimally invasive surgery within a relatively short period of time using relatively low energy.

While the present invention has been described with respect to certain preferred embodiments, it will be apparent to a person having ordinary skill in the art that various changes and modifications may be made without departing from the scope of the invention as defined in the following claim.

What is claimed is:

1. A surgical robot system comprising,
 - a plurality of robot arms;
 - a surgery actuator, wherein the surgery actuator is controlled in a pitch direction and/or in a yaw direction by at least one of the plurality of robot arms, and
 - wherein the surgery actuator comprises at least one tool for minimally invasive surgery, and
 - wherein the at least one tool for minimally invasive surgery comprises a main shaft, a first actuating shaft, a second actuating shaft, an end effector and a handling part, and
 - wherein the handling part controls the first actuating shaft, the second actuating shaft and the end effector; and
 - a base, wherein the base comprises a vertical arm and a horizontal arm, and

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wherein the vertical arm operates in a surge direction and in a roll direction, and the horizontal arm operates in a pitch direction, and

wherein the surgery actuator is further controlled in a surge direction and/or in a roll direction by at least one of the plurality of robot arms, and

wherein the surgery actuator comprises at least two tools for minimally invasive surgery, and

wherein the at least two tools for minimally invasive surgery are positioned in parallel to each other, and

wherein the handling part comprises a plurality of drive pulleys, and

wherein each of the plurality of drive pulleys is driven by a drive roller, and

wherein the handling part further comprises a plurality of actuating pulleys, and

wherein each of the plurality of actuating pulleys is driven by at least one of the plurality of drive pulleys, and

wherein the plurality of actuating pulleys control the first actuating shaft, the second actuating shaft and/or the end effector, and

wherein the at least one tool for minimally invasive surgery further comprises a first yaw actuating part connecting the main shaft and the first actuating shaft, a second yaw actuating part connecting the first actuating shaft and the second actuating shaft, and a pitch actuating part connecting the second actuating shaft and the end effector, and

wherein the first yaw actuating part is connected to one of the plurality of actuating pulleys by a yaw cable, and

wherein the pitch actuating part, the first yaw actuating part and the second yaw actuating part are connected to the rest of the plurality of actuating pulleys by a first pitch cable and a second pitch cable.

2. The surgical robot system as claimed in claim 1, wherein the surgery actuator further comprises an endoscope.

3. The surgical robot system as claimed in claim 2, wherein the endoscope and the at least one tool for minimally invasive surgery form a bundle.

4. The surgical robot system as claimed in claim 2, wherein the endoscope and the at least one tool for minimally invasive surgery are controlled in a surge direction and/or in a roll direction to the surgery actuator, respectively.

5. The surgical robot system as claimed in claim 1, further comprising a main control part, wherein the main control part comprises at least one joystick and at least one adjusting lever, and

wherein the at least one joystick controls the surgery actuator, and the at least one adjusting lever controls the at least one tool for minimally invasive surgery.

6. The surgical robot system as claimed in claim 5, wherein the at least one joystick further controls an endoscope positioned at the surgery actuator.

7. The surgical robot system as claimed in claim 5, wherein at least one portion of the at least one joystick is handled in a surge direction, in a pitch direction, in a yaw direction and in a roll direction.

8. The surgical robot system as claimed in claim 5, wherein the at least one adjusting lever comprises a first handling rod, a second handling rod, a third handling rod, a first rod and a second rod,

wherein the first handling rod, the second handling rod and the third handling rod are connected in sequence by a first yaw rotation axis and a second yaw rotation axis, wherein the third handling rod is connected to the first rod and the second rod by a pitch rotation axis, and

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wherein the motion of the first handling rod corresponds to that of the main shaft, the motion of the second handling rod corresponds to that of the first actuating shaft, the motion of the third handling rod corresponds to that of the second actuating shaft, and the motions of the first rod and the second rod correspond to those of the end effector.

9. The surgical robot system as claimed in claim 8, wherein the at least one tool for minimally invasive surgery further comprises a third actuating part or a connecting part connecting the second actuating shaft and the end effector,

wherein the main control part further comprises a pedal, and

wherein the motion corresponding relations between the handling rods and the shafts are variable according to handling the pedal.

10. The surgical robot system as claimed in claim 5, wherein the main control part further comprises a pedal, and wherein the motion corresponding relation between the at least one adjusting lever and the at least one tool for minimally invasive surgery is variable.

11. A surgical robot system comprising, a plurality of robot arms;

a surgery actuator, wherein the surgery actuator is controlled in a pitch direction and/or in a yaw direction by at least one of the plurality of robot arms, and

wherein the surgery actuator comprises at least one tool for minimally invasive surgery, and

wherein the at least one tool for minimally invasive surgery comprises a main shaft, a first actuating shaft, a second actuating shaft, an end effector and a handling part, and wherein the handling part controls the first actuating shaft, the second actuating shaft and the end effector; and

a base, wherein the base comprises a vertical arm and a horizontal arm, and

wherein the vertical arm operates in a surge direction and in a roll direction, and the horizontal arm operates in a pitch direction, and

wherein the surgery actuator is further controlled in a surge direction and/or in a roll direction by at least one of the plurality of robot arms, and

wherein the surgery actuator comprises at least two tools for minimally invasive surgery,

wherein the at least two tools for minimally invasive surgery are positioned in parallel to each other, and

wherein the handling part comprises a plurality of drive pulleys, and

wherein each of the plurality of drive pulleys is driven by a drive roller, and

wherein the handling part further comprises a plurality of actuating pulleys, and

wherein each of the plurality of actuating pulleys is driven by at least one of the plurality of drive pulleys, and

wherein the plurality of actuating pulleys control the first actuating shaft, the second actuating shaft and/or the end effector, and

wherein the at least one tool for minimally invasive surgery further comprises a first yaw actuating part connecting the main shaft and the first actuating shaft, a second yaw actuating part connecting the first actuating shaft and the second actuating shaft, and a pitch actuating part connecting the second actuating shaft and the end effector, and

wherein the first yaw actuating part is connected to a first actuating pulley of the plurality of actuating pulleys by a first yaw cable, and

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wherein the second yaw actuating part is connected to a second actuating pulley of the plurality of actuating pulleys by a second yaw cable, and

wherein the pitch actuating part is connected to a third actuating pulley of the plurality of actuating pulleys by a pitch cable, and

wherein the end effector is connected to a first drive pulley of the plurality of drive pulleys by an opening and closing cable.

12. The surgical robot system as claimed in claim 11, wherein the at least one tool for minimally invasive surgery further comprises a third yaw actuating part connecting the second actuating shaft and the end effector, and

wherein the third yaw actuating part is connected to a fourth actuating pulley of the plurality of actuating pulleys by a third yaw cable.

13. The surgical robot system as claimed in claim 11, wherein the surgery actuator further comprises an endoscope.

14. The surgical robot system as claimed in claim 13, wherein the endoscope and the at least one tool for minimally invasive surgery form a bundle.

15. The surgical robot system as claimed in claim 13, wherein the endoscope and the at least one tool for minimally invasive surgery are controlled in a surge direction and/or in a roll direction to the surgery actuator, respectively.

16. A surgical robot system comprising, a plurality of robot arms;

a surgery actuator, wherein the surgery actuator is controlled in a pitch direction and/or in a yaw direction by at least one of the plurality of robot arms, and

wherein the surgery actuator comprises at least one tool for minimally invasive surgery, and

wherein the at least one tool for minimally invasive surgery comprises a main shaft, a first actuating shaft, a second actuating shaft, an end effector and a handling part, and wherein the handling part controls the first actuating shaft, the second actuating shaft and the end effector; and

a base, wherein the base comprises a vertical arm and a horizontal arm, and

wherein the vertical arm operates in a surge direction and in a roll direction, and the horizontal arm operates in a pitch direction, and

wherein the surgery actuator is further controlled in a surge direction and/or in a roll direction by at least one of the plurality of robot arms, and

wherein the surgery actuator comprises at least two tools for minimally invasive surgery, and

wherein the at least two tools for minimally invasive surgery are positioned in parallel to each other, and

wherein the handling part comprises a plurality of drive pulleys, and

wherein each of the plurality of drive pulleys is driven by a drive roller, and

wherein the handling part further comprises a plurality of actuating pulleys, and

wherein each of the plurality of actuating pulleys is driven by at least one of the plurality of drive pulleys, and

wherein the plurality of actuating pulleys control the first actuating shaft, the second actuating shaft and/or the end effector, and

wherein the at least one tool for minimally invasive surgery further comprises a first yaw actuating part connecting the main shaft and the first actuating shaft, a second yaw actuating part connecting the first actuating shaft and the second actuating shaft, and a connecting part connecting the second actuating shaft and the end effector, and

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wherein the first yaw actuating part is connected to a first actuating pulley of the plurality of actuating pulleys by a first yaw cable, and

wherein the second yaw actuating part is connected to a second actuating pulley of the plurality of actuating pulleys by a second yaw cable, and

wherein the connecting part, the first yaw actuating part and the second yaw actuating part are connected to the rest of the plurality of actuating pulleys by a first pitch cable and a second pitch cable.

17. The surgical robot system as claimed in claim 16, wherein the surgery actuator further comprises an endoscope.

18. The surgical robot system as claimed in claim 17, wherein the endoscope and the at least one tool for minimally invasive surgery form a bundle.

19. The surgical robot system as claimed in claim 17, wherein the endoscope and the at least one tool for minimally invasive surgery are controlled in a surge direction and/or in a roll direction to the surgery actuator, respectively.

20. A surgical robot system comprising,
a plurality of robot arms;

a surgery actuator, wherein the surgery actuator is controlled in a pitch direction and/or in a yaw direction by at least one of the plurality of robot arms, and

wherein the surgery actuator comprises at least one tool for minimally invasive surgery, and

wherein the at least one tool for minimally invasive surgery comprises a main shaft, a first actuating shaft, a second actuating shaft, an end effector and a handling part, and wherein the handling part controls the first actuating shaft, the second actuating shaft and the end effector; and

a base, wherein the base comprises a vertical arm and a horizontal arm, and

wherein the vertical arm operates in a surge direction and in a roll direction, and the horizontal arm operates in a pitch direction, and

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wherein the surgery actuator is further controlled in a surge direction and/or in a roll direction by at least one of the plurality of robot arms, and

wherein the surgery actuator comprises at least two tools for minimally invasive surgery,

wherein the at least two tools for minimally invasive surgery are positioned in parallel to each other, and

wherein the handling part comprises a plurality of drive pulleys, and

wherein each of the plurality of drive pulleys is driven by a drive roller, and

wherein the handling part further comprises a plurality of actuating pulleys, and

wherein each of the plurality of actuating pulleys is driven by at least one of the plurality of drive pulleys, and

wherein the plurality of actuating pulleys control the first actuating shaft, the second actuating shaft and/or the end effector, and

wherein the at least one tool for minimally invasive surgery further comprises a first yaw actuating part connecting the main shaft and the first actuating shaft, a second yaw actuating part connecting the first actuating shaft and the second actuating shaft, and a pitch actuating part connecting the second actuating shaft and the end effector, and

wherein the first yaw actuating part is connected to a first actuating pulley of the plurality of actuating pulleys by a first yaw cable, and

wherein the second yaw actuating part is connected to a second actuating pulley of the plurality of actuating pulleys by a second yaw cable, and

wherein the pitch actuating part is connected to a third actuating pulley of the plurality of actuating pulleys by a pitch cable.

21. The surgical robot system as claimed in claim 20, wherein the surgery actuator further comprises an endoscope.

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